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STUDIES ON MORPHOLOGICAL SOLONETZ
SOILS OF ALBERTA

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University of Alberta.

A thesis submitted to the University of Alberta
in partial fulfilment of the requirements for the degree
of Master of Science.

April, 1938.

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Studies on Morphological Solonetz Soils of Alberta

by

J. M. MacGregor

Introduction

A relatively large area in south-eastern Alberta is composed of slightly alkaline soils with a characteristic morphological solonetz profile. The presence of eroded and irregular shallow pit-like depressions, usually several feet across, and commonly designated as "blow-outs" or "burn-outs" are the most noticeable feature of the micro-relief of the area. The term "morphological solonetz" has been used to designate these soils since the vertical profile exhibits characteristic solonetz structure, but apparently lacks the typical solonetz chemistry. Solonetzic soil profiles are characterized by the development of a relatively impervious, strongly columnar B₁ horizon, whereas no such pronounced structures occur in normal soil profiles. This development has been attributed to the presence of relatively large proportions of sodium at one period, though such concentration may no longer be present. Solonetz soils are usually found in regions where sufficient salts to term the soil "alkali" still occur.

The presence of alkali in soils was observed and methods of reclaiming such areas were studied long before scientists were able to account for their origin. However, it was not until 1894 that the presence of columnar horizons in alkali soils was first pointed out by Zemiatchensky. This phenomenon of the soil profile has now been observed in many parts of the world which are located in arid or semi-arid regions.

At the present time, considerable difference of opinion still exists as to the evolution of alkali soils. In general, theories of Russian investigators as to the origin of these soils have been followed to a great degree. Gedroiz postulated that relatively large proportions of sodium in the soil were necessary to evolve the columnar structure and physical properties now present. More recently it has been noted by such workers as Kelley and Nikiforoff that the morphology of at least some of these soils does not agree with the present chemical content. It has been said that the study of exchangeable bases with the previous determination of soluble bases has been the cornerstone in regard to the study of alkali soils.

Theory of Evolution of Alkali Soils

Hilgard defined alkali soils as those containing excessive amounts of soluble salts of continental origin. He designated them as a result of climate and was the first to put forth a scientific theory regarding their origin.

de'Sigmond (5) concluded from his investigation that the factors responsible for the formation of alkali soils were:

- (1) An arid or semi-arid climate.
- (2) An impervious subsoil or hard-pan layer.
- (3) A temporary abundance of humidity in the soil, intersected with dry periods.

In English speaking countries the term alkali soil simply means saline soil, the salts of which may be the sulphates, chlorides, carbonates or nitrates of such bases as sodium, magnesium and calcium. Russian scientists felt the need of a more specific term, and divided alkali soils into three main groups.

- (1) "Solonchak" soils--saline soils which contain an abundance of soluble salts.
- (2) "Solonetz" soils-- alkaline soils which contain relatively much replaceable sodium.
- (3) "Solod", "Solodi" or "Soloth" soils--soils which were formerly solonetzic, but in which the exchangeable sodium has now largely been removed and exchangeable hydrogen substituted-- a degraded solonetz soil.

The morphological features of these soils are characterized by the extremely well developed profile of the solonetz in which the relatively impervious B_1 horizon constitutes the most important character, whereas both the solonchak and soloth have comparatively little profile development in this horizon.

The main features of the Gedroiz theory as to the origin and evolution of these soils is outlined by Nikiforoff (24) as follows:

"Normal soil. (brown soil). In these soils the base exchange is largely saturated with the divalent cations, the

colloids are in a flocculated state and the soil is nearly neutral. The calcification process is dominant."

"Solonchak (saline soil). In this case there is an excess of soluble salts especially sodium, and also usually some portion of the divalent cations. The presence of the excess salts prevents the hydrolysis of the sodium from the exchange and keeps the colloids flocculated. The soil is not highly alkaline. This process is best called salinization."

"Solonetz (alkali soil). These soils have a relatively high percentage of exchangeable sodium in the complex and a low percentage of soluble salts. As the drainage of the solonchak becomes improved, the excess soluble salts are removed. In such cases where these salts were essentially all divalent, the soil changes back to normal. In most instances, however, the solonchak contains considerable amounts of exchange sodium, such that when the excess salts are removed the colloids are given increased mobility and the soil becomes highly alkaline as a result of the hydrolysis of the sodium to form sodium hydroxide. Because of the deflocculated state of the colloidal portion, the soil exhibits a prismatic structure with hard aggregates. This process is called solonization and might be said to consist of desalinization plus alkalization."

"Soloth. As soon as the solonetz has formed, the highly dispersed colloids tend to move downward in the solum. In a sense this process is similar to podsolization, except that the original mobility of the colloids is due to exchange sodium rather than to exchange hydrogen. The exchange capacity of

the soil becomes reduced, and the pH. becomes lower with the increase in exchangeable hydrogen. A light colored A₂ horizon with a platy structure and a light texture develops over a dark hard columnar B horizon. With the completion of the development, the B horizon loses its columnar structure and itself becomes somewhat acid. This process is called solodization."

"Normal soil. After the complete formation of soloth with the removal of the mobile colloids, the continued growth of the native grasses again changes the soil to the normal for that region. This process of calcification impinged on the soloth might be termed reconstruction."

Shaw and Kelley (30) recently have shown that the terms "solonetz" and "solonchak" are used in two senses, vix. morphologically and chemically. They point out that considerable confusion in the use of the terms now exist due to the occurrence of soils with the typical solonetz morphology, but lacking solonetz chemistry.

Nikiforoff (22) states that as well as the typical solonetz, there is a great group of soils alkalized to lesser degree. The chemical features of these are the presence of exchangeable sodium but in relatively small proportions. The physical and morphological features are the compactness of the solonized section of the profile. They possess all the properties of a solonetz but in a smaller degree and such soils are much more common than the typical solonetz.

The Occurrence of Solonized Soils

Solonized soils in varying degree appear to be almost world wide in distribution where low precipitation occurs. Russian investigations on these soils are numerous and de' Sigmond (5) has reported on their presence in Hungary. Nevros and Zvorykin (25) have reported a solonetz red soil in Attica.

Storie (33), Kelley (17), Nieschmidt(21), Murphy and Daniel (20), Fieger and Sturgis (7), Rost (28), Kellogg (13), and Nikiforoff (23), have reported on morphological solonetz soils in various parts of the United States. Ellis and Caldwell (6) found a magnesium clay solonetz in southern Manitoba and Mitchell and Riecken (19) report the occurrence of solonized soils in southern Saskatchewan. The presence of eroded spots appears to be a characteristic feature in some of these areas at least.

Soil Origin and the Morphology of Solonetz

Soils in Alberta

A brief description of soil formation and development in general is of importance. Soils in Alberta have originally been derived from two sources:

(1) Those soils which have been deposited upon the parent shales or sandstones by glacial action, the glacial deposits being referred to as glacial "drift" or "till". These are the glacial or transported soils.

(2) Those soils which have developed "in situ" from weathering of the parent sandstone and shales.

The larger proportion of soils in Alberta are of the former type. However, it is important to note that in the south-eastern portion of the province the present deposition of glacial "till" for the most part is relatively thin, in many cases the parent shales and sandstones being exposed. In this case it is difficult to distinguish and state definitely the origin of these soils, but it is reasonable to assume that at least a portion of these soils might be more correctly designated residual soils.

Normal soil profiles are characterized by three general horizons, namely, A, B, and C.

A is the surface horizon and is that portion of the soil which has undergone weathering.

The B horizon is immediately below the A, and is the horizon of accumulation of various products which have passed downward by various means from A.

The C horizon, being parent material by definition, varies widely - being sandstones or shales in Alberta.

It is necessary to divide the two upper horizons into two or more subdivisions:

A₁- The horizon of grass root accumulation, and where leaching has not been extensive.

A₂- Usually a lighter colored horizon, where leaching has occurred to a greater extent.

B₀- Transition horizon between A and B. It includes the flaked off portions of the B.

B₁- The horizon into which the colloidal matter from the A horizon has been leached - the horizon of colloid

accumulation.

B₂, B₃, B₄ - the lowest horizon usually indicates an accumulation of electrolytes - most of them being precipitated as the carbonate.

Typical solonetz profiles likewise are characterized by the development of the general horizons A, B, and C. The A₁ horizons of the solonetz profiles have no well developed structure, and do not differ materially in appearance from the A horizons of normal soils. However, the solonetz soil profiles differ decidedly in the following characters which are rarely found in normal profiles.

(1) The presence of a light colored extremely leached, ashy A₂ horizon immediately on top of the B. This varies in thickness from a mere film to 2-3 inches.

(2) The occurrence of a relatively impermeable, deflocculated, highly colloidal B₁ horizon in which columnar structural development is at a maximum. The upper surfaces of these columns, where well developed, are often termed "round-tops" from their characteristic biscuit-like appearance.

Where erosion of the A horizon has occurred, the crevices between these columns have been filled with highly dispersed colloidal clay, resulting in a smooth impermeable washed clay surface. The entire upper B horizon is extremely colloidal and is almost impervious to water.

The lower B horizons do not differ materially in structure from such horizons in normal soil profiles though the kind and concentrations of the various chemical constituents may not be similar.

Plate I



Cross-sectional View of a
Solonetz Profile

(Note the weakly developed A
horizon in contrast to the
structural development of
the B.)



View of A Badly Eroded Solonetz Area

(Note the absence of erosion on the hill
in the background)

A common micro-relief feature of a badly solonized area is the presence of erosion spots termed "blow-outs". If the surface is impermeable to water with no vegetation present, the eroded surface at the top of the B horizon presents a white washed appearance and gives rise to the name of "slick" spots. Such areas present a serious problem for agricultural utilization.

The Significance of Base Exchange in Solonized Soil Studies

The study of saline and alkali soils has of necessity involved the determination of exchangeable bases in soils, it being first necessary to extract the soluble bases from the soil, or to determine them on a similar sample and apply a correction on the amount of exchangeable bases determined.

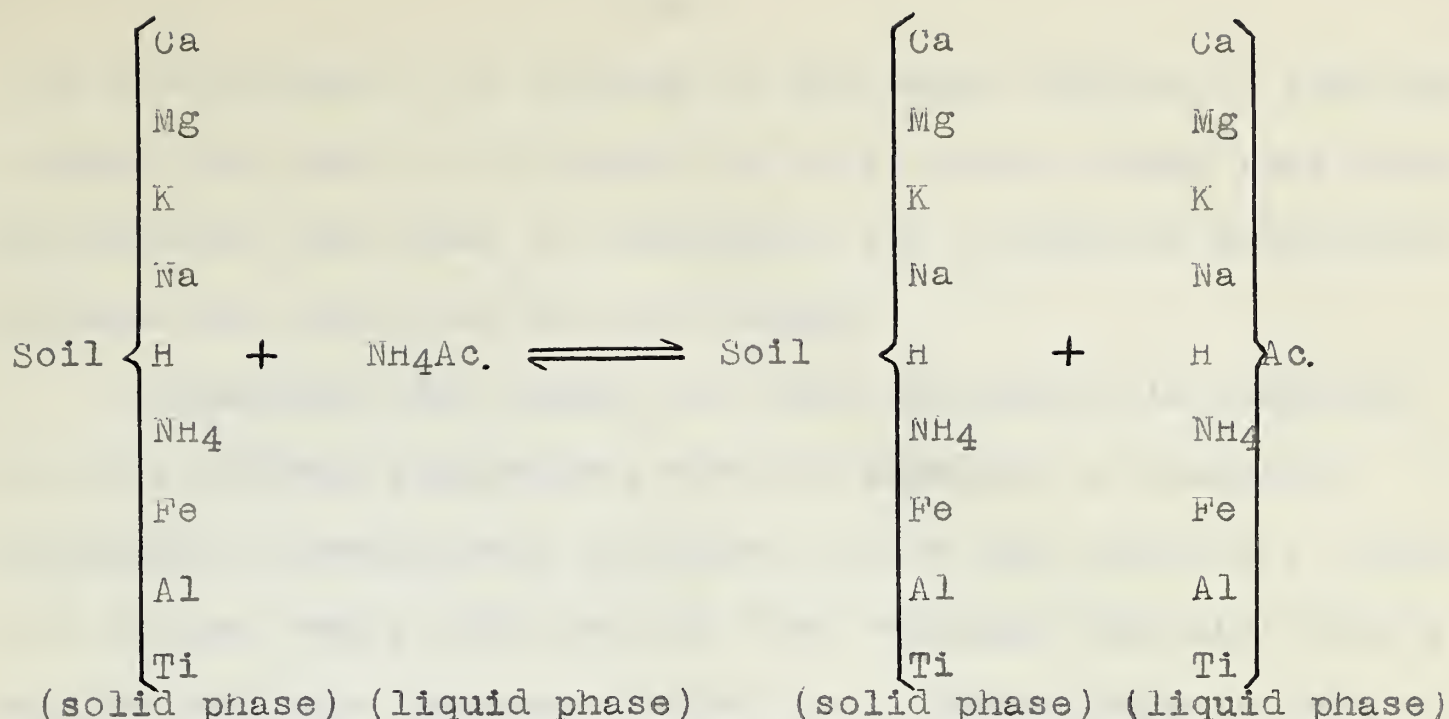
Gedroiz and others have shown that the physical properties of soils are influenced by the exchange complex. When sodium is substituted for the divalent bases, the granular structure of the clay material is broken down with the eventual development of extreme impermeability. If sodium is present in sufficient quantities and proportions, hydrolysis to sodium carbonate is the result. When calcium is the dominant base, the clay particles tend to assume the form of aggregates, and the soil is then relatively porous. Hissink found that when a sample of sodium-saturated heavy clay was shaken with water and allowed to stand, it showed practically no sedimentation after seven months. The same clay when saturated with calcium settled out quickly. Kelley and Brown (15) state that the relative degree of dispersion of a soil when saturated

with different bases stands in the order $\text{Ca} < \text{Mg} < \text{K} < \text{Na} < \text{Li}$. which is the exact order of hydration of their respective ions. It would seem that the hydration of ions is closely connected with the physical properties of soils.

Murphy and Daniel (20) studied erosion or "slick spots" of central Oklahoma in relation to the relative dispersion coefficients of the exposed B_1 and the nearly normal A horizons, and noted significant differences in the settling time necessary; a much longer time being required for the colloidal B_1 solution to settle out.

The Reactions Involved in Base Exchange

It has been known for almost a century that when a soil is treated with a neutral salt solution, the base of the salt is fixed in the soil with the corresponding release of a number of soil bases, - in other words, a part of the base of the displacing neutral salt solution displaces an equivalent amount of the soil bases. The former passes out of solution and becomes a component of the soil complex, and the latter passes into solution and may then be leached away, provided that insoluble compounds are not formed. When chlorides, nitrates or acetates are used as the anion of the leaching salt solution, the salts formed by base exchange are highly soluble, but the use of carbonates and phosphates leads to the formation of insoluble precipitates. The process of ion exchange may be illustrated as follows:



The exchange reaction is subject to the principles of mass action and chemical equilibrium. Kelley and Brown (14) found that it requires an extracting solution strength slightly greater than half normal to effect complete extraction, normal solutions being used as a general rule. The usual shaking and filtering of soil solutions is not satisfactory. Leaching the soil continually disturbs the equilibrium by removing the soluble products of the reaction, which will eventually go to completion, or approximately so. In the case of ammonium acetate being used as the leaching salt, NH_4 will then remain in the soil as the only replaceable base.

Van Bemmelen concluded that the replaceable bases are adsorbed in the surface of the colloidal particles of the soil, and are not held as ordinary chemical compounds. Hissink (10) investigated the speed of the exchange process, and found that 97 per cent of the exchangeable bases went into solution in the first five seconds. From this he concluded that only adsorbed bases are replaceable, since the reaction was too rapid

for the cations to be located on the inner surface of the particles, the rate of diffusion in solid bodies being very slow. He believes the cause of adsorption was a chemical attraction between the bases and the soil acids.

Stephenson (32) points out that adsorption is conceded to be a surface phenomenon, whether physical or chemical. Adsorption formerly was considered to be due entirely to physical forces, but at the present time evidence indicates that it may be entirely chemical or that it is unnecessary to make a distinction between chemical and physical forces in such reactions. Soil minerals are attacked chemically only at the surfaces. The reaction goes on with great rapidity because the colloidal particles are small and present a large surface area per unit weight, and the reaction is limited to surfaces. The reaction per unit area may be the same as for coarse particles.

The Identification of the Base Exchange Complex

Since the publication of the classical investigations of Way in 1852 on base exchange in soils, several investigators have reported on the nature of the complex responsible for the interchange of bases. Way noted that the clay fraction of the soil exhibited exchange properties to the greatest degree and suggested that the inorganic exchange constituents of soils belonged to the alumino-silicates, which are analogous to the zeolites. Gedroiz holds that replaceable bases occur either as humates or in zeolitic forms.

Kelley, Dore and Brown (16) compared bentonite, natural zeolites and soil colloids chemically and by X-ray analysis. They decided that the properties of the zeolites were not the same as soil colloids or bentonite since:

(1) Grinding the soil colloids and the bentonite brought a marked increase in base exchange properties, but did not in the case of the natural zeolites.

(2) Heating to 350° C destroyed the exchange properties of the zeolites, whereas it required a temperature of 750° C to destroy similar properties in the soil colloids and bentonite.

(3) X-ray analysis indicated that the zeolites did not have the typical diffraction patterns of the bentonites and soil colloids, consequently their exchange properties cannot be due to the same substance.

(4) Natural zeolites are relatively unstable substances formed as the result of the weathering of feldspars, and it is reasonable to assume that they would undergo complete disintegration within a short time. Soil colloids are relatively stable substances.

They found that substances composing the colloidal material of soils are not amorphous, but crystalline, and replaceable bases occur not only on the surface of the particles, but also on the interior of the crystals. X-ray analysis revealed an orderly arrangement of the atoms within the particles, and since the exchange of bases is stoichiometric, they conclude that base exchange substances are true chemical compounds.

Stephenson (32) states that the exchange complex apparently is identical with the colloidal fraction of soils, and it is unnecessary to distinguish between organic and inorganic complexes as the source of the exchange reaction since both are colloids and are thus responsible for exchange reactions.

The Error Involved in the Determination of
Exchangeable Bases

Kelley and Brown (14) point out that soils may contain bases in at least four forms:

- (1) Exchangeable bases--those held by the exchange complex.
- (2) Water soluble salts, such as chlorides, nitrates and sulphates.
- (3) Carbonates.
- (4) The crystalline phosphates and silicates.

The main source of error in the determination of replaceable bases is the presence of the carbonates in considerable quantities in soils, although the crystalline silicates and phosphates also present lesser difficulties. The reaction which takes place between the leaching electrolyte solution and the base exchange material involves an exchange of ions which does not hold true in other cases. It is well known that calcium carbonate is soluble in solutions of ammonium salts, and when calcareous soils are being studied, it is not uncommon to find that the calcium equivalent of the dissolved carbonate may exceed the replaceable calcium. Hissink (9) developed a method of eliminating this error by leaching with

two successive litres of solution. Since the exchange reaction is extremely rapid and solution rates should be the same, he reasoned that differences in calcium content between these two successive leachates should represent the exchangeable calcium. Chapman and Kelley (4) report this method as not very accurate. Gedroiz advocated a determination of the carbonate content of the soil before and after extraction. Kelley and Brown (14) found this method to be quite accurate provided that the total carbonates did not exceed 1 per cent of the soil and where magnesium carbonate does not occur.

Methods of Determining Exchangeable Bases

Three main procedures have been developed, all of which involve the previous elimination of soluble salts, or the determination of soluble salts on a separate sample and the application of a correction.

(1) Electrodialysis. Largely utilized by Mattson (18) and has also been used by several workers with success. Wilson (34) and Bradfield (2) have reported upon this method. However, it is subject to the same errors as the other methods when the alkaline earth carbonates are present.

(2) Leaching with Dilute Acid Solutions. Gedroiz (8) reported that when a soil is leached with dilute HCl, the bases are replaced by hydrogen. Kelley and Brown (14) found that dilute HCl, when used in this way, not only attacks substances normally involved in replacement reactions, but others as well.

(3) Leaching with Neutral Salt Solutions. This is the most common method. The neutral salts commonly used are NH_4Cl or NH_4Ac .

Choice of Neutral Leaching Salt.

Sodium chloride was the first salt so employed, but since sodium was one of the important bases to be determined, ammonium salts were utilized, either the chloride or the acetate. Holowaychuk (11) found that either of these salts produced closely agreeing results and that the acetate had several advantages.

Schollenberger and Dreibelbis (29) state the following desirable qualities of NH_4Ac as a leaching agent.

- (1) "It has pronounced buffer properties around pH. 7.
- (2) It is easily expelled by a simple evaporation.
- (3) It is inexpensive and easily prepared."

The Problem

The problem undertaken in this investigation was to obtain specific information regarding the chemical composition of morphological solonetz soils in Alberta. In this investigation, attempts were made to obtain information as follows:

(1) To determine if the morphological solonetz soils of Alberta were similar to those in other parts of the world, both in exchangeable and water soluble bases.

(2) To find if any appreciable differences in base content

existed between profiles selected in the centre of the eroded "slick-spots" and non-eroded profiles immediately adjacent.

(3) To determine if appreciable differences in base content or relative proportion existed between the above soils and those located at some distance from the erosion spots on the same general level.

(4) To report any significant differences existing in the relative ratio and content of water soluble and exchangeable divalent bases to sodium, in soils of the solonized areas and of adjacent areas where soils are normal in structure.

(5) To compare total exchange capacity of these Alberta solonetz soils with the total exchange capacity occurring in the Alberta black and the grey wooded soil zones as well as with other normal soils in different parts of the world.

(6) To determine the relative proportions and amounts of the divalent bases to sodium in the strongly developed solonized profiles.

(7) To report upon the total base exchange capacity of these soils and determine if any base unsaturation existed in either normal or solonized profiles.

(8) To determine if the degree of profile development could be correlated with relative amounts and proportions of sodium in comparison to the divalent bases.

(9) To study the relative solubilities of water and normal ammonium acetate upon lime plaster, calcium carbonate and hydrated calcium sulphate, the latter two being common relatively soluble substances in the lower soil horizons.

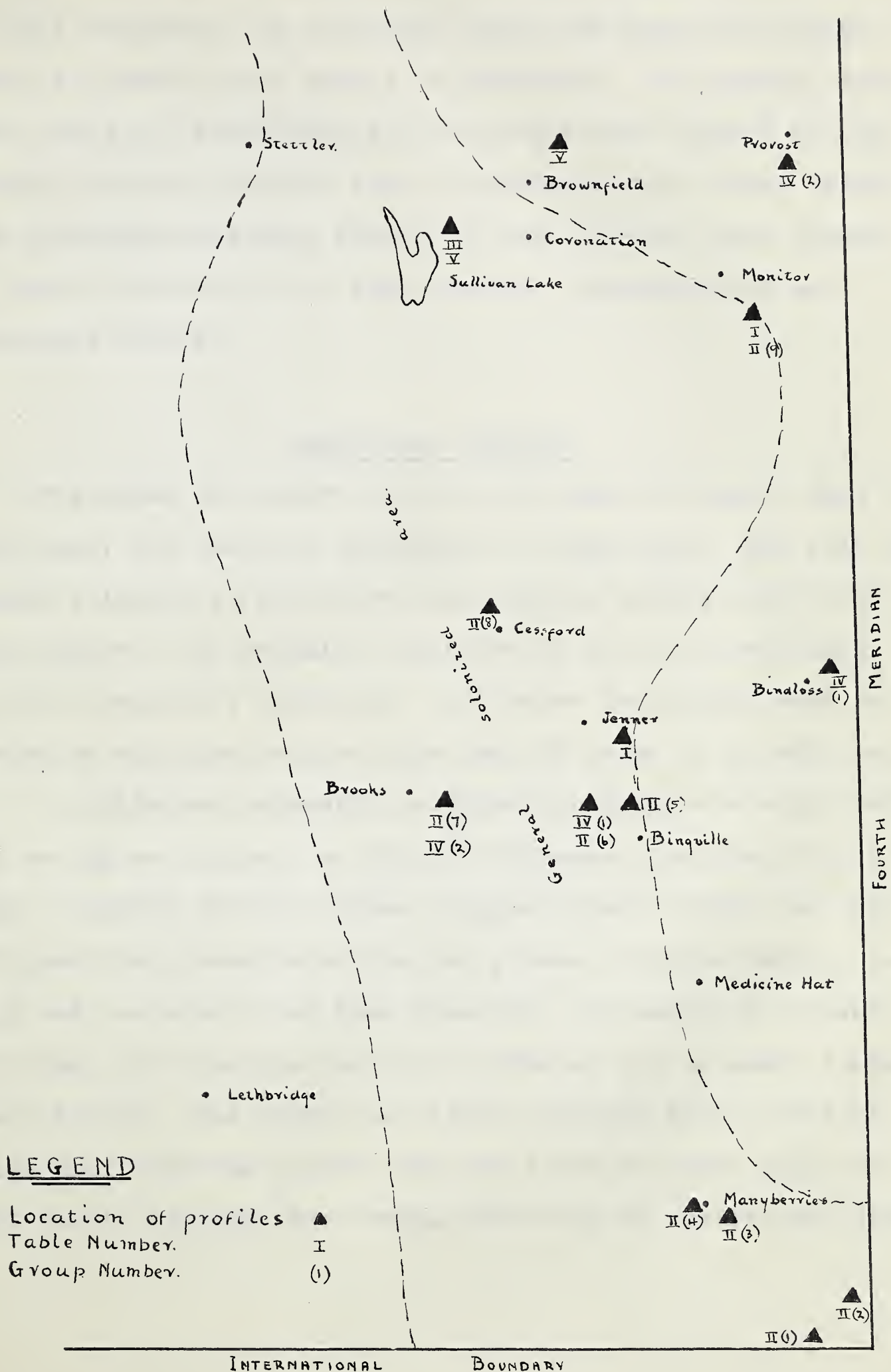
(10) To correlate these findings with the relationship

that apparently exists between the presence of morphological solonetz soils, and the probable causal and stabilizing factors of such soils as climate, topography, drainage and soil types.

The extent of the major solonized soils in Alberta can be seen from the accompanying map. However, the area outlined represents only that portion of the province, where due to climatic and other factors these soils have a decided tendency to form. It should be emphasized that solonized soils are practically limited to level or undulating areas, the more rough topography being normally little affected. There appears to be the drainage factor involved in their formation, as well as climate. However, more weakly developed morphological solonetz soils may be seen in many other parts of the province than that area outlined. Usually these areas occur on comparatively level lands and as scattered localized phenomena, they can be observed in the black soils around Edmonton.

Solonization, then is a common occurrence in the brown and dark brown soil zones of the province, and is of more rare occurrence in the black soil zone. In all probability this is essentially due to inadequate drainage as well as to the lower precipitation and higher evaporation rates in the more solonized areas. The brown and dark brown soil zones have a lower average annual precipitation than is found in the black soil zone to the north and west.

Map of Southeastern Alberta



LEGEND

Location of profiles ▲
 Table Number. I
 Group Number. (1)

INTERNATIONAL BOUNDARY

FOURTH MERIDIAN

It was also noted that soil types in the same region vary in their degree of solonization and erosion, silt loams being much the most susceptible. Loams are more intermediate in this tendency, the extremely light and heavy soil types being in general more normal in character. In general, solonized soils are associated with the more arid regions of the earth's surface; climate and a topography which tends to allow inadequate drainage appear to have been the main factors in their formation, soil types being a secondary and more localized factor.

Analytical Methods

Ten grams of air-dry soil was the size of sample used in each case, and each was determined in duplicate. The soil was ground slightly to pulverize lumps and to secure a more uniform sample. The granular structure of the soil particles was not completely destroyed. All bases determined were reported as milligram equivalents per 100 grams of air-dry soil.

A continuous automatic leaching apparatus was used, which was set up as follows: a 1000C.C. florence flask was fitted with a tightly fitting rubber stopper through which two holes had previously been bored and two pieces of glass tubing (one long and one short) had been inserted. By means of a stand and ring, the florence flask was inverted over a small U-shaped glass funnel. The funnel was first equipped with a disc of glass wool over the outlet tube and a mat of paper pulp was laid on top (special care being exercised to prevent the glass

wool strands extending along the sides of the glass past the paper pulp which might cause channelling.) Then the ten gram soil sample was placed on the paper mat followed by a close fitting disc of filter paper to prevent the soil from washing. The glass funnel outlet was equipped with a stop-cock which was necessary to adjust the rate at which leaching proceeded.

The end of the shorter tube in the florence flask stopper extended just below the top of the glass funnel, the air entering the flask through this tube until immersed by the rise of leaching solution in the funnel, which in turn had to leach through the soil and lower the level of leaching solution in the funnel before air was again admitted to the flask and the solution again delivered through the longer tube into the funnel.

The leaching rate was adjusted at approximately 12-15 drops per minute, and it required eighteen to twenty-four hours to leach with a 750 c.c. volume of solution.

The soil was first leached with 500 c.c. of CO_2 -free water to remove soluble salts. The leachate was then evaporated to approximately 50 c.c. on a steam bath, filtered, washed with hot water, and made up to volume. Aliquots of this solution were then analyzed for Ca, Mg, Na, and sulphates.

The extraction of replaceable bases was then carried out by leaching the same soil sample with 750 c.c. of normal ammonium acetate adjusted to a pH. of 6.9, immediately following the water leaching. This leachate was evaporated to dryness to dehydrate any silica present, then treated with 25 c.c. of concentrated nitric acid and again evaporated to dryness to

destroy any organic matter present. The nitrates were then converted to chlorides by treating with 25 c.c. of concentrated hydrochloric acid and evaporating to dryness. Then the residues were taken up with a few c.c.'s of concentrated hydrochloric, approximately 100 c.c.'s of water added and filtration and washing with hot water then carried out. The solutions were then made up to volume and aliquots taken for the determination of exchangeable Ca, Mg, and Na. The sulphates were also determined in this leachate, but in general due to their high solubility, these were present mainly in the water leachate.

After the acetate leachate was removed, the soil was immediately saturated with calcium, by leaching with 750 c.c. of normal calcium chloride solution. Then the excess calcium (that which was theoretically not held by the exchange complex) was removed by leaching with distilled water, until the leachate gave no further test for calcium. The soil was then leached with 750 c.c. of normal ammonium acetate solution. The leachate thus obtained was treated in a similar manner as the exchange leachate, but analyzed for calcium only. The milligram equivalents per 100 grams of soil in this solution were considered to be a measure of the total base exchange capacity.

Calcium was determined by precipitating as the oxalate and titrating with 0.05 N. KmnO_4 .

Magnesium was determined by evaporating the calcium oxalate filtrate to a low volume and treating with a 10 per cent microcosmic salt ($\text{NaNH}_4\text{HPO}_4$) solution, brought down under ammoniacal conditions and let stand over-night. The precipitate

was filtered off in the morning, air dried, dissolved in standard H_2SO_4 and titrated with standard NaOH .

The sodium was determined gravimetrically, being precipitated as the triple salt-uranyl zinc sodium acetate-according to Barber and Kolthoff (1).

Sulphates were determined gravimetrically by precipitating with 10 per cent BaCl_2 solution, filtered, and ignited in the muffle furnace to a temperature of 700°C .

Potassium was not determined.

Errors Involved in the Method

Chapman and Kelley (4) have emphasized the complexity and number of interfering factors involved in such investigations, and the difficulty of securing good results. Leaching the soil with a neutral salt solution for any extended period, tends to introduce errors by dissolving bases which do not occur in the soil in the exchange form.

In this investigation, 500 c.c. of CO_2 -free water was used to extract the soluble salts. It was decided to continue extraction with a second similar quantity from ten soil samples, to determine if further soluble bases were obtained. In each case it was found that the second leachate contained further bases, principally the less soluble calcium and magnesium, and the amounts, though small, indicated that extended leaching continues to extract smaller amounts of the bases. This would indicate that a portion of the so-called exchangeable bases could be removed as water soluble, if water leaching was continued for some period.

It is also well known that solutions of neutral salts have a greater solubility effect upon some soil constituents than has water. It was decided to carry out an experiment to compare the leaching effects of water and normal ammonium acetate solution upon three materials which had been mixed in pure sand, in such proportions that about 5 per cent of the ten grams of material leached in each case, consisted of calcium. The materials used were lime plaster, C. P. CaCO_3 and C. P. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, since the latter two, are two of the principal constituents introducing the solubility error. The amount of the leaching solution used in each case was 750 c.c.s. Excellent duplicate results were obtained and the analyses are given below.

Comparison of Solubility Effects of Water and Normal Ammonium Acetate Solution on Various Substances.

<u>Composition of Sample</u>	<u>Leaching Solution</u>	<u>Mgm. Ca</u>	<u>Mgm. SO_4</u>
	750 c.c.		
2 gms. lime plaster			
+ 8 gms. sand -----	CO_2 -free H_2O	25.7	trace
2 gms. lime plaster			
+ 8 gms. sand -----	Normal NH_4Ac	231.3	trace
1.3 gms. CaCO_3 (500mgm. Ca)			
+ 8.7 gms. sand -----	CO_2 -free H_2O	15.4	none
1.3 gms. CaCO_3 (500mgm. Ca)			
+ 8.7 gms. sand -----	Normal NH_4Ac .	164.5	none
2.2 gms. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (500 mgm. Ca)			
+ 7.8 gms. sand -----	CO_2 -free H_2O	254.4	58.2
2.2 gms. $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (500 mgm. Ca)			
+ 7.8 gms. sand -----	Normal NH_4Ac	447.2	105.8

The preceding results indicate the serious error introduced in the determination of exchange bases by the presence of the various carbonates, and by high concentrations of the sulphates. Both carbonates and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) occur more or less abundantly in the lower B horizons of most soils--rarely in the upper horizons in any amounts.

The normal ammonium acetate solution extracted greater amounts of calcium from each of the three substances than was extracted by an equal volume of water. The amount in excess of the water extraction apparently was considerably greater wherever calcium occurred in the sample as the sulphate. The acetate solution extracted approximately eleven times the amount extracted by the water, in the case of the CaCO_3 sample; nine times the amount where the lime plaster was leached (since the sulphate form is relatively more water soluble), and not quite twice the amount in the case of the $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. Thus it would seem that if any of these substances remain in the soil after the water leaching, that the succeeding acetate solution will remove greater quantities, this being especially true of the $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (gypsum), since it is approximately three times more soluble in the acetate solution than the CaCO_3 . However, the $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ is approximately seventeen times more soluble in water than is the CaCO_3 . This would indicate that relatively much greater quantities of the $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ would be dissolved with the water leaching. It could be assumed that unless an extremely high percentage of the sulphate form occurred in the soil, it would largely be removed by the water extraction and would then be classed as water soluble forms. However, where

the carbonates are present in the soil, usually as CaCO_3 , due to their low water and high acetate solubility, serious error in the determination of exchange calcium results.

In several cases it was found impossible to leach the highly impermeable colloidal B_1 horizons with water. This made it necessary to obtain an extract by some other method in order to determine the soluble bases. This was done by using suction on a Berkefeld filter candle. Then a fresh soil sample was leached with the acetate solution, and the amount of water soluble bases subtracted from the exchangeable bases found. This procedure involved a new error. It frequently happened that one sample of the B_1 horizon would leach whereas its duplicate would not, in which case suction filtering was carried out. Upon analysis, it was found that although soluble calcium and magnesium results agreed closely in the two extraction methods, the sodium content of the Berkefeld filtered extract was much higher than the leached sample on the same soil. It was also noted in several cases where both duplicates had to be suction filtered, and a fresh sample leached with acetate to determine exchangeable bases, that the water extracted soluble sodium obtained by the Berkefeld filtered duplicates did not agree and were often in excess of the total exchange sodium found.

The error was traced to sodium remaining in the filters from more concentrated soil solution extractions--although these filters had been thoroughly washed and leached with distilled water. It is emphasized that when suction filtering a

more concentrated soil solution such as 1:5, sodium adsorption by the Berkefeld candle does not interfere. It appears that the more dilute solutions emphasize any error involved through adsorption of sodium from previous, and especially more concentrated, soil solutions.

Parker (27) has reported on the adsorption of phosphates by the Pasteur-Chamberland filters when dilute soil extracts were used. He concluded that the adsorption of phosphorus was largely due to soil colloids held in the pores of the filter candle, since new filters did not adsorb phosphorus. Pasteur-Chamberland filters are composed of unglazed porcelain, whereas the Berkefeld filters are of infusorial or diatomaceous earth composition. It would seem logical that the adsorption of Na by these filters would be due to much the same cause. It is suggested that when filtering dilute soil extracts for either sodium or phosphate, that several litres of distilled water be suctioned through each candle prior to the dilute soil solution.

The sodium content of the B₁ horizon was of considerable importance in this investigation, and where water leaching was impossible, it was necessary to use some other method of extraction whereby a similar amount of sodium could be extracted to that obtained by the leaching method. A soil profile was leached and the water soluble sodium extracted determined. Then the same profile samples were shaken on an end-over-end shaker for thirty minutes with water in various concentrations, filtered, and made up to volume and sodium determined on an aliquot. The results are given below.

Water Soluble Sodium Extracted By Leaching and Shaking Methods

(in m.e. per 100 grams air-dry soil)

<u>Sample No.</u>	<u>Horizon</u>	<u>Leaching</u>		<u>Shaking</u>	
		<u>1:50</u>	<u>1:5</u>	<u>Berkefeld filtered</u>	<u>Paper filtered</u>
				<u>1:50</u>	<u>1:100</u>
258	A ₁	0.17	0.15	*6.75	0.35
"		0.17	0.14	*0.87	0.38
259	A ₂	0.17	0.11	*0.99	0.35
"		0.17	0.10	*0.51	0.33
260	B ₁	0.26	0.12	0.24	0.44
"		0.27	0.14	0.31	0.44
261	B ₂	1.36	0.58	1.01	1.58
"		1.44	0.63	1.17	1.50
262	C	4.55	1.80	3.37	4.28
"		4.55	1.83	3.64	4.35

*Errors introduced by using contaminated Berkefeld filters.

The preceding analyses show in the first column the sodium extracted by leaching ten grams of soil with 500 c.c.'s of water-a ratio of 1:50. The three succeeding columns indicate the sodium extracted by shaking the same soil samples for thirty minutes in the varying concentrations of soil and water, namely, 1:5, 1:50, and 1:100. The filtering after shaking in the case of the 1:5 and 1:50 solutions was done by means of Berkefeld filter candles using suction. No significant contamination from the filters occurred in the case of the 1:5 solution, but contamination was particularly marked in the first four samples of the 1:50 solution. Filtering was done with three

candles, which were washed, leached with distilled water and used again the same order, i.e. one candle was used to filter the first, fourth, seventh, and tenth solutions, etc. As the candles were repeatedly used with the dilute soil solutions, the contamination rapidly became insignificant, especially with increasing water soluble sodium content of the soil. This leads to the conclusion that suctioning with a considerable quantity of distilled water previous to filtering such dilute soil solution, should remove any appreciable amounts of sodium present in the filter. It is of interest to note, that contamination, if present in the 1:5 solutions, is not significant. However, the solution which is ten times more dilute (1:50) rapidly extracts sodium from the filter candles, and the later concentration of such solution for analysis greatly emphasizes such contamination.

Folded filter papers were used to filter the 1:100 soil solution to minimize possibilities of sodium contamination.

Shaking with the 1:100 solution (last column) apparently gave the most comparable results to the leaching method (first column), especially where the concentrations of soluble sodium were high as in the two lower horizons (samples #261 and #262). In the 1:100 shaken solution some of the exchangeable sodium in the upper horizons has evidently been extracted as water soluble sodium since approximately twice as much sodium has been extracted by this method as by the leaching. Where such discrepancies between the two methods occur, the soluble sodium content in such horizons is low. Where it was necessary to

make an extraction for soluble sodium in this manner, sodium was always quite abundant. Good comparisons of the different extraction methods as to sodium content were obtained in the solonized B₁ horizons.

It should be kept in mind in any soil analysis comparison, that profiles selected a short distance from each other may vary considerably in base proportion and content, due to natural variations in the soil. Kellogg (13) has pointed out that the most common occurrence of the solonchak, the solonetz and the soloth soils is as a complex. Within an area which in some places has an approximately normal profile, there occur irregular patches of the solonized complex, and these patches are usually not uniform in any characteristic. The original solonchak which was dominant throughout the area at one time, may have had almost any ratio of the various bases (present as salts) in the saline water. Thus the resulting solonetz structure will vary from an almost normal profile, through a weakly developed solonized structure to the extremely hard solonetz morphology, depending on the ratio of monovalent to divalent bases which were present in the original solonchak. These bases may have risen in irregular patches from the water table, or may have saturated the soil from the surface. Thus considerable variability in base content and the ratio of divalent to monovalent bases might be expected to occur in soils within relatively short distances, especially in solonized areas. In the analyses presented, such variations are seen.

Experimental Results

The main results of this investigation are set out in Tables I to V. Each table actually consists of two parts, e.g. Table I and Table IA. Each table number represents a comparison of one aspect of the investigation. However, in some cases several comparison studies were made to study the same aspect, and in this case they were given the same table number, but each comparison was given a group number e.g. Table II Group I etc. In the first table in each case is given the profile, horizon, depth from the surface, water soluble and exchangeable Ca, Mg, and Na, in M.e. per 100 grams of air-dry soil, and water soluble and acetate extracted sulphates in milligrams per 100 grams of soil. In a few cases sulphates were not determined.

The last two columns present the total base exchange capacity of each horizon. Total base exchange capacity refers to the quantity of cations which the soil is capable of holding in a form that is replaceable by, and stable in, neutral solutions of Ca, Mg, Na, K and NH_4 salts. This was determined in two ways, with the exception of a few group comparisons in Table II, where the results are not given for the last column. In the first of the last two columns the total base exchange capacity is found by adding together the three exchange bases determined. This is not a true measure of total base exchange capacity, since only the three major exchange bases were reported. Small amounts of K, Fe, Al, Ti, Mn, etc. would also be present in the exchange complex as well as hydrogen. However the sum of the three major bases determined should ap-

proximate the total exchange capacity unless large quantities of hydrogen are present, since the bases which were not determined usually occur in very small quantities.

In the last column in the table, the amounts representing the total base exchange capacity have been obtained by resaturating the base exchange complex with calcium after having removed the exchange bases by N. NH_4Ac . This amount should represent the true base exchange capacity.

Considerable variation exists in these two columns, especially in the lower B horizons. However, where the amount given in the last column is decidedly greater than the amount in the previous column, the major part of this difference is attributed to the presence of hydrogen in the exchange complex of the soil and that horizon is then termed "unsaturated" with respect to the bases. This occurs in the A horizons of only two of the profiles studied and is generally attributed to a high hydrogen content in that horizon actually having displaced some of the exchange bases originally present. Where the amounts in the last column are smaller than in the preceding column, this error is attributed to base containing substances mentioned previously which are highly soluble in N. NH_4Ac . solution. Thus some of the bases determined as exchangeable (principally calcium), have not been present in the soil in the exchange form but rather as simple salts or crystalline materials. This is a common feature of the lower B horizons, where the determination of exchange bases, especially calcium, is highly erroneous.

The second table (Table A) of each comparison group presents the results given in the first table of the comparison, but in a different form. This table is divided into four sections. The first section presents the amount of each water soluble base as a percentage of the total of the three bases determined. The second section presents in the same manner relative percentages of the exchange bases extracted. The fourth section gives the sum of each of the total bases extracted in milligram equivalents per 100 grams of soil, that is, the water soluble and exchange calcium were added together to give the total extracted calcium. Total extracted magnesium and sodium were obtained in the same way. The third section presents the results of the fourth section in a similar manner to those presented in the first two sections of the table. This often gives a different picture, due to the differences in the ease of extraction of the various bases.

Table I.

All base exchange investigations lead to the conclusion that the exchange complex resides chiefly in the soil colloids, hence it is to be expected that a heavy clay soil would have a much greater exchange capacity than an extremely sandy soil. In the course of this investigation, the exchange properties of an apparently solonized heavy clay flat were determined. Since like determinations were also carried out on a sandy soil, a comparison of the two are present. These two profiles were of necessity collected considerable distances from each other.

Water soluble Na appears to be important throughout the clay profile, whereas it is not so important or present in such quantities in the sandy loam soil, but in the latter profile it does increase rapidly with depth. High sulphate content in all horizons where Na occurs in marked amounts suggests the presence of the soluble Na_2SO_4 . The higher concentration of sodium in the clay flat indicates little, or no percolation of water, whereas the removal of salts by the downward percolation of water has been extensive in the sandy soil profile. The water soluble Ca and Mg of the upper horizons is much as expected, these being smaller in amount in the sandy soil. If any great amounts of Ca or Mg other than exchangeable do occur in the upper horizons of the clay profile, they probably exist mainly in the carbonate form, rather than as the highly water soluble sulphate, the sulphate in these horizons being mainly united to Na. The water soluble Ca and Mg in the lowest horizon of both profiles occur in such amounts that large quantities apparently exist as the sulphate. The water soluble Ca extracted from the B₂ horizon of the clay profile, exceeds by far the amounts which were extracted with water in any other profile examined in this investigation. We may say that the lowest horizon of the clay profile is very high in the sulphates of Ca and Mg whereas the Na_2SO_4 occurs in considerable quantities throughout the profile. The sandy loam profile is low in water soluble salts, with considerable accumulation of the sulphates of Ca, Mg, and Na in the B₃ horizon.

The exchange constituents determined show some sulphate still present in both profiles, which was not removed with the

water extraction. This has led to considerable error in the exchange bases determined, as can be seen by comparing the last two columns of the table (base exchange capacity results) with each other. It is seen that wherever the acetate extraction contained no sulphate, the two columns of total base exchange capacity agree very well. Thus much of the exchange bases determined throughout the clay profile, and in the lowest horizon of the sandy loam profile, actually occurred in the soil not in the exchange form, but in soluble forms such as the sulphate or carbonate, the error thus caused being especially great in the lower horizons. To obtain a more accurate idea of what the total amount of exchange bases should be, one should consult the last column of the table. The differences between these amounts and those in the preceding column illustrate the magnitude of the error introduced by solubility effect in this case. The last column, however, shows that the clay profile has several times the exchange capacity of the sandy loam and also contains much greater amounts of water soluble bases in various forms. This would suggest very little percolation of water through the clay profile. Some of the Ca reported as exchange Ca in the B₂ horizon of the clay profile must have existed in the soluble sulphate form, since sulphate content in this horizon is high and Mg and amounts of Na are relatively low.

The sandy loam profile is not as low in exchange bases as might be expected for a soil of this class. However, both water soluble and exchangeable base content is low in the upper

horizons of this soil when compared with the clay flat profile, until the B₃ horizon is reached. No unsaturation is evident in either profile.

Table I A.

The results from Table I are here presented in another form. The water soluble percentages show the dominance of the soluble Na salts in the upper horizons of both profiles. However, in the lowest horizon of each profile, the less soluble Ca and Mg sulphates are the dominant water soluble salts present.

The percentages of the exchange bases determined show the dominance of the divalent bases in both profiles. However, in all horizons of the clay profile, and in the lowest horizon of the sandy profile, this dominance should not be so marked, as much of the exchange Ca and Mg determined was actually present in the soil in the water soluble form.

The percentage of total extracted bases indicates that Na is relatively more important in the sandy loam than in the clay profile, though total extracted divalent bases are still much the dominant bases in both profiles.

The m. e. of total extracted bases shows the high content of the various types of bases in the clay flat profile, where accumulation might have occurred from surrounding areas; bases in the soluble form being very abundant, and evidently little salt removal from the flat has occurred. Total bases in the sandy soil are low and percolation and leaching of bases to lower horizons is suggested.

We may state from the results of this comparison (Tables I and I A) that the clay flat profile has a high content of

water soluble salts, these occurring mainly as the sulphates of Ca, Mg, and Na. Exchange base content in the clay flat soils is much higher than in sandy soils, but the differences decrease as the soil type becomes heavier. Soils which are high in organic matter contain greater amounts of exchange bases than such clay flats as this.

The conclusion of this investigation is that low-lying clay flats occurring in solonized areas, due to their very high content of soluble salts, and relatively low per cent of exchange Na, could be more truly termed 'solonchak' soils rather than 'solonetz', even though some morphological indications of the solonetz are present. It might also be pointed out that in analyzing such soils for exchange bases, the great amount of soluble salts to be removed from the soil require at least 1000 c.c.'s of water leachate to effect complete removal and so not produce errors in the amount of exchange bases determined.

At the start of this investigation it was thought that there existed a possibility of some significant differences in either water soluble or exchange base content, or the proportions of sodium to the divalent bases, if profiles from the same area, but showing variations in structure development and nearness to erosion, were studied.

Profiles were selected from -

- (1) The centre of an eroded or "blow-out" spot.
- (2) The side of an eroded or "blow-out" spot.
- (3) Some distance away from the other profiles, fairly well removed from any erosion.

The possibility existed that the relative proportion or content of exchangeable bases might have some bearing upon the occurrence of erosion.

The number of profiles selected in each group varied from two to four, and nine group sets of profiles were collected and analyzed. Each group represents comparisons of profiles which were all taken within a radius of a few hundred feet, and yet these profiles exhibited some differences in structural development.

Table II. Group I.

This group of profile comparisons consists of two profiles, one eroded and the other non-eroded, selected from an undulating, solonized, fine sandy loam area. The two profiles were selected 28 inches from each other, the main object in this case being to determine if any significant differences in base content were present in the profiles which might indicate the cause of the erosion. Sulphates and total base exchange capacity were not determined in these profiles.

Water soluble Na occurs in both profiles in amounts varying from 1 m. e. to 4 m. e. approximately. The greater quantities were found in the B₁ (round-top), and the B₂ horizons. Water soluble Ca and Mg compared to Na are low, indicating little of these bases as the sulphate. Appreciable amounts of exchange Na also occur in both profiles, particularly in the B₁ horizons. The exchangeable divalent bases occur in much greater quantities than are present in the water soluble form. In the lowest horizons of both profiles, the amounts

of these divalent bases are so great, that it appears that some soluble base substances have been dissolved in these horizons. Since total base exchange capacity was not determined, it is impossible to state this definitely.

The A table shows that water soluble Na practically equals the sum of the two divalent bases, and this base increases rapidly with depth. The proportion of exchange Na to the divalent bases is not so great in either profile and constitutes from 5 to 35 per cent of the total. The percentages of total extracted bases show that Na is an important base in both profiles, and while not dominant in any horizon, the relative effectiveness of Na in soil deflocculation may cause it to be a much more significant factor in solonized soil profiles than it appears here.

The conclusions of this comparison are that no significant differences in base content which might cause erosion were found. As with all heavily solonized soils, Na constitutes an appreciable proportion of the bases, though it is not in excess of the two divalent bases in any horizon.

Table II. Group II.

This two profile group comparison was taken from an undulating solonized, fine sandy loam area. The profiles were selected only a few feet apart, and the eroded profile, though grassing over on the eroded surface, still exhibited the strongly solonized morphology, whereas the non-eroded profile showed less development. This comparison was made for similar reasons as in Group I. Sulphates and total base exchange capacity were only determined on the B₂ horizons of each profile.

Water soluble bases show an increase of Na with increasing depth, though this does not appear to be present as the sulphate. Since both profiles are relatively shallow, sulphates may be present at greater depths, beyond the lime horizon. Water soluble Na is slightly greater in amounts in each horizon of the eroded profile. These differences are insignificant since the divalent bases also occur in greater amounts.

The exchange base analyses show greater amounts of Na in the eroded than in the non-eroded profile. However, the exchangeable divalent bases have increased greatly, especially in the lower horizons, and total base exchange capacity results (compare last two columns of table) show that considerable error has been introduced in the B₂ horizons by solubility effect, indicating probable carbonate accumulations.

The A table shows that water soluble Na in the non-eroded profile occurs in as great or greater proportions than the water soluble divalent bases, which holds true only in the lowest horizon of the eroded profile. The relatively high proportion of the water soluble divalent bases present, may be one explanation for the invasion of grasses upon the eroded surface. The proportion of exchangeable Na is relatively low in both profiles, the greater concentrations occurring in the B₁ horizons. Here the effect of Na content on the degree of structural development is marked, since the eroded profile B₁ is much better developed and also contains relatively much more Na. Exchangeable divalent bases are markedly dominant in both profiles. Total extracted base percentages again show higher Na content in the better developed profile B₁ horizon,

this being almost double the proportion of Na in the less solonized non-eroded B₁.

The conclusions of this group comparison are that no significant differences in base content of the two profiles occur which might account for erosion. The eroded profile does contain more Na throughout, both in amounts and in relative proportions to the divalent bases. These differences do not seem to be sufficiently great to be significant. The degree of development of the solonized B₁ horizons appears to be correlated with exchangeable Na content. Percolation of water evidently tends to lower the Na content and thus produces a more normal profile structure.

Table II Group III.

This comparison consists of three profiles, being selected to the center, at the side and about 30 feet distant from the erosion respectively. The eroded profile represents a relatively large area from which the surface has been removed, and this profile is intermediate in structural development to the other two profiles. The second profile which was taken at the edge of the erosion, exhibits a strongly solonized structure, whereas the third profile is practically normal in this respect, being taken from a slightly higher level. The area is undulating in topography and the surface soil is a fine sandy loam.- Sulphates were not determined.

The most significant feature of the water soluble base analyses, is the difference exhibited by the third and most

normal profile, in having much lower amounts of soluble salts present throughout than are found in the first two profiles. These two profiles contain appreciable amounts of soluble Na throughout, and the relatively high water soluble Ca and Mg content of the B₂ horizons suggests the presence of considerable amounts of the sulphates of Ca and Mg, as well as Na₂SO₄. The presence of this greater concentration of soluble salts in the more heavily solonized profiles than are present in the third profile can most easily be explained by differences in elevation or by the presence of a more impermeable subsoil.

In the exchangeable base analysis the first two profiles again are so near alike in base content that they again can be considered as a unit in discussing the results. The higher content of exchange Na is evident in both B₁ horizons. Here again exchange Na in the third profile is much lower. In all three profiles, the exchangeable divalent bases are much in excess of the exchange Na.

Total base exchange capacity (see last two columns of the table) indicates that only slight differences exist in the three profiles. In each case there is evidence of some CaCO₃ in various parts of the profile, but it apparently does not occur in any great quantities. Base unsaturation evidently does not occur in any of these three profiles.

Table A. -- shows that the proportion of water soluble Na to the water soluble divalent bases present in all three profiles to be much the same, and appears to about equal them in proportion in some cases. In the percentage of exchangeable bases, Na is slightly lower in the more normal profile, though the divalent bases are greatly dominant in all three profiles.

Table I. Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity in Solonized Profiles from a Heavy Clay Flat and a Sandy Loam Area (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity			
				Bases as m. e.			Bases as m. e.						
				Ca	Mg	Na	Mgms. SO4	Ca	Mg		Na	Mgms. SO4	Sum'n
343	A	0"-6"	massive & columnar	1.2	0.6	4.6	Profile 115	32.8	17.2	3.6	trace	53.6	38.0
344	B1	6"-12"	hard & massive	0.8	0.2	8.3	116	38.5	14.6	3.1	trace	56.2	42.0
345	B2	12"-	massive salt and lime horizon	79.5	12.7	11.1	5200	92.0	7.5	0.6	1812	100.1	38.0
575	A1	0"-8"	loose, sandy	0.2	0.2	0.4	Sandy Loam Profile none	3.8	1.3	0.6	--	5.7	6.8
576	A2	8"-9"	loose, leached	0.2	0.2	0.5	none	2.5	1.0	0.6	--	4.1	4.4
577	B1	9"-13"	hard "round-tops"	0.4	0.6	1.2	none	3.6	7.7	2.1	--	13.4	14.0
578	B2	13"-16"	cloddy	0.4	0.6	2.9	108	11.1	3.2	1.0	--	15.3	16.8
579	B3	16"-24"	powdery, little structure	13.4	7.5	5.5	1271	80.0	47.0	0.9	354	127.9	22.4

Table IA. Percentage comparison of water soluble, exchangeable, and total extracted bases, and M.E. of total extracted bases in solonized profiles from a heavy clay flat and a sandy loam area.

Sample No.	Hori- zon	Percentage Milligram Equivalents										Mgm. Equivalents				
		Water Soluble Bases					Exchange Bases					Total Extracted Bases				
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na			
Clay Flat Profile																
343	A	19	9	72	61	32	7	57	30	13	34.0	17.8	8.2			
344	B1	9	89	68	26	6	60	23	17	39.3	14.8	11.4				
345	B2	77	12	11	92	7	84	10	6	171.5	20.2	11.7				
Sandy Loam Profile																
575	A1	25	25	50	67	23	10	62	23	15	4.0	1.5	1.0			
576	A2	22	22	56	61	24	15	54	24	22	2.7	1.2	1.1			
577	B1	18	27	55	27	57	16	26	53	21	4.0	8.3	3.3			
578	B2	10	16	74	73	21	6	60	20	20	11.5	3.8	3.9			
579	B3	51	28	21	62	37	1	61	35	4	93.4	54.5	6.4			

Table II. Group I. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity in Adjacent Eroded and Non-eroded Solonized Fine Sandy Loam Profiles. (per 100 grams of air-dry soil)

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity
				Bases as m. e.			Mgms.			
				Ca	Mg	Na	Ca	Mg	Na	
241	A2	0"-15"	light grey-brown hard "round-tops". taken to lime	Eroded Profile						
				0.6	0.4	0.9	2.5	2.5	0.7	5.7
242	B1	1.5"-3"		1.9	0.8	3.4	6.2	6.1	1.4	13.7
243	B1	3"-4"		0.8	0.4	1.1	18.8	10.2	2.9	31.9
				Non-eroded Profile						
235	A1	0"-2"	light-brown, platy cloddy dark brown fair "round-tops" compact	0.4	0.4	0.5	4.5	0.8	0.7	6.0
236	A2	2"-6"		0.6	0.4	0.9	3.9	2.9	1.3	8.1
237	B1	6"-6.5"		1.5	1.2	1.4	3.8	5.7	5.2	14.7
238	B1	6.5"--11"		0.5	0.4	3.7	19.7	13.5	8.7	41.9
240	B2	11"-		0.8	0.4	4.0	62.3	12.7	3.8	78.8

Table IIA. Group I. - Percentage Comparison of Water-soluble, Exchangeable, and Total Extracted Bases and M. E. of Total Extracted Bases in Adjacent Eroded and Non-eroded Solonized Fine Sandy Loam Profiles.

Sample No.	Hori- zon	Percentage Milligram Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
		Eroded Profile												
241	A2	32	21	47	44	44	12	41	38	21	3.1	2.9	1.6	
242	B1	31	13	56	45	45	10	41	35	24	8.1	6.9	4.8	
243	B1	35	17	48	59	32	9	57	31	12	19.6	10.6	4.0	
Non-eroded Profile														
235	A1	31	31	38	75	13	12	68	16	16	4.9	1.2	1.2	
236	A2	32	21	47	48	36	16	45	33	22	4.5	3.3	2.2	
237	B1	37	29	34	26	39	35	28	37	35	5.3	6.9	6.6	
238	B2	11	9	80	47	32	21	43	30	27	20.2	13.9	12.4	
240	B3	15	8	77	79	16	5	75	16	9	63.1	13.1	7.8	

Table IIA - Group II. - Percentage Comparison of Water-soluble, Exchangeable and Total Extracted Bases and M. E. of Total Extracted Bases in Adjacent Eroded and Non-eroded Solonized Fine Sandy Loam Profiles.

		Percentage Milligram Equivalents										Mgm. Equivalents					
Sample No.	Hori- zon	Water Soluble Bases					Exchange Bases					Total Extracted Bases			Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
Eroded Profile (Grassed over)																	
212	A2	42	29	29	40	7	53	51	38	11	6.6	4.9	1.5				
213	B1	33	39	28	48	10	42	41	46	13	15.3	17.3	4.7				
214	B2	28	7	65	25	2	73	70	24	6	49.9	16.9	4.6				
Non-eroded Profile																	
215	A1	25	25	50	35	2	63	60	34	6	6.1	3.5	0.6				
216	A2	20	20	60	34	4	62	59	32	9	6.3	3.5	1.0				
217	B1	44	8	48	33	4	63	62	31	7	23.4	11.6	2.7				
218	B2	34	9	57	13	2	85	83	13	4	82.5	13.2	3.5				

Table II. Group III. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity in Adjacent Eroded and Non-eroded Solonized Fine Sandy Loam Profiles.
(per 100 grams of air-dry soil.)

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity		
				Bases as m. e.			Bases as m. e.			Mgms.	Sum'n	m. e.
				Mgms.			Mgms.			SO ₄		
				Ca	Mg	Na	Ca	Mg	Na			
275	A2	1"-6"	Leached	0.3	0.4	0.8	Eroded Profile			--	8.0	7.6
276	B1	6"-8"	granular	0.6	1.0	2.6	--	--	--	--	28.9	27.2
277	B2	8"-12"	granular	1.2	1.2	4.4	--	--	--	--	37.5	27.6
278	B3	12"-	salts	7.7	2.2	3.7	--	--	--	--	27.6	21.3
269	A1	0"-1.5"	cloddy	0.3	0.4	0.6	--	--	--	--	13.7	14.4
270	A2	1.5"-3"	platy	0.2	0.6	0.9	--	--	--	--	10.1	10.5
271	B1	3"-7"	"round-tops"	2.2	2.2	3.0	--	--	--	--	28.9	33.0
272	B2	9"-14"	columnar	0.5	1.2	4.2	--	--	--	--	31.1	29.5
273	B3	9"-14"	salts	6.5	2.9	3.6	--	--	--	--	25.6	23.3
274	B4	14"-	no salts	0.3	0.8	1.8	--	--	--	--	14.2	14.4
264	A1	0"-1.5"	little structure	0.4	0.4	0.9	--	--	--	--	13.1	17.1
265	A2	1.5"-4"	no plates	0.1	0.4	0.6	--	--	--	--	14.0	15.7
266	B1	4"-8"	columnar	0.5	0.8	0.6	--	--	--	--	24.4	23.3
267	B2	8"-12"	granular	0.2	0.6	0.6	--	--	--	--	15.2	13.8
268	B3	12"-	no lime	0.2	0.6	0.6	--	--	--	--	10.7	10.1

Table IIA. Group III. - Percentage Comparison of Water-soluble, Exchangeable and Total Extracted Bases and M. E. of Total Extracted Bases in Adjacent Eroded and Non-eroded Solonized Fine Sandy Loam Profiles.

Sample No.	Hori- zon	Percentage Milligram Equivalents										Mgm. Equivalents		
		Water Soluble Bases					Exchange Bases					Total Extracted Bases		
		Total Extracted Bases					Total Extracted Bases					Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Ca	Mg	Na	Ca	Mg	Ca	Mg	Na
275	A2	20	27	53	61	25	14	55	20	5.2	2.4	1.9		
276	B1	14	24	62	70	24	6	63	13	20.8	8.1	4.2		
277	B2	18	18	64	75	22	3	67	12	29.5	9.4	5.4		
278	B3	57	16	27	73	22	5	67	13	27.7	8.3	5.2		
269	A1	23	31	46	69	27	4	66	7	9.8	4.1	1.1		
270	A2	12	35	53	61	29	10	54	16	6.4	3.5	1.9		
271	B1	30	30	40	64	26	10	57	16	20.7	9.8	5.8		
272	B2	9	20	71	65	29	6	56	16	20.8	10.2	6.0		
273	B3	50	22	28	74	22	4	66	12	25.3	8.6	4.7		
274	B4	10	28	62	58	32	10	50	19	8.5	5.3	3.3		
264	A1	24	24	52	68	28	4	63	9	9.3	4.1	1.4		
265	A2	9	36	55	68	29	3	64	6	9.6	4.5	1.0		
266	B1	26	42	32	66	32	2	63	4	16.6	8.6	1.1		
267	B2	14	43	43	62	35	3	58	6	9.7	5.9	1.0		
268	B3	14	43	43	56	38	6	51	10	6.2	4.7	1.2		

Table II. Group IV. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Normal and Solonized Fine Sandy Loam Profiles in the Same General Area. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity			
				Bases as m. e.			Bases as m. e.			m. e.			
				Mgms.			Mgms.			Sum'n			
				Ca	Mg	Na	Ca	Mg	Na	SO ₄	CaCl		
				Normal Profile (Manyberries)									
258	A ₁	0"-1.5"	flaky	1.0	0.4	0.2	none	13.4	4.4	0.3	none	18.1	20.6
259	A ₂	1.5"-5"	weakly columnar	0.7	0.2	0.2	none	9.0	3.8	0.3	none	13.1	14.6
260	B ₁	5"-19"	columnar, not compact	0.7	0.2	0.3	none	11.8	6.9	0.3	none	19.0	19.2
261	B ₂	19"-48"	lime deposition	1.4	1.1	1.4	none	65.0	12.3	0.5	none	77.8	59.6
262	C	48"-96"	parent shales	1.4	0.2	4.5	90	57.0	16.7	0.6	none	74.3	37.0
263	C	96"-	parent shales	10.2	1.3	5.0	1050	61.0	10.2	0.5	trace	71.7	28.5
269	A ₁	0"-1.5"	little structure	0.3	0.4	0.6	none	9.5	3.7	0.5	none	13.7	14.4
270	A ₂	1.5"-3"	grey, platy	0.2	0.6	0.9	none	6.2	2.9	1.0	none	10.1	10.5
271	B ₁	3"-7"	columnar "round-tops"	2.2	2.2	3.0	trace	18.5	7.6	2.8	none	28.9	33.0
272	B ₂	7"-9"	columnar	0.5	1.2	4.2	trace	20.3	9.0	1.8	none	31.1	29.5
273	B ₃	9"-14"	salt horizon	6.5	2.9	3.6	trace	18.8	5.7	1.1	none	25.6	23.3
274	B ₄	14"-	horizon below salt	0.3	0.8	1.8	trace	8.2	4.5	1.5	none	14.2	14.4

Table IIA. Group IV. - Percentage Comparison of Water-soluble, Exchangeable and Total Extracted Bases and M. E. of Total Extracted Bases of Normal and Solonized Fine Sandy Loam Profiles in the Same General Area.

Sample No.	Horizon	Percentage Milligram Equivalents										Mgm. Equivalents		
		Water Soluble Bases					Exchange Bases					Total Extracted Bases		
		Total Extracted Bases					Total Extracted Bases					Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
258	A1	62	25	13	74	24	2	73	24	3	14.4	4.8	0.5	
259	A2	64	18	18	69	29	2	68	28	4	9.7	4.0	0.5	
260	B1	58	17	25	62	36	2	62	35	3	12.5	7.1	0.6	
261	B2	36	28	36	83	16	1	81	17	2	66.4	13.4	1.9	
262	C	23	3	74	77	22	1	73	21	6	58.4	16.9	5.1	
263	C	62	8	30	85	14	1	81	13	6	71.2	11.5	5.5	
Normal Profile (Manyberries)														
Solonized Profile														
269	A1	23	31	46	69	27	4	66	27	7	9.8	4.1	1.1	
270	A2	12	35	53	61	29	10	54	30	16	6.4	3.5	1.9	
271	B1	30	30	40	64	26	10	57	27	16	20.7	9.8	5.8	
272	B2	9	20	71	65	29	6	56	28	16	20.8	10.2	6.0	
273	B3	50	22	28	74	22	4	66	22	12	25.3	8.6	4.7	
274	B4	10	28	62	58	32	10	50	31	19	8.5	5.3	3.3	

Table II. Group V. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Adjacent Eroded and Non-eroded Weakly Solonized Glacial Loam Profiles. (per 100 grams of air-dry soil)

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity					
				Bases as m. e.			Mgms.			Bases as m. e.			Mgms.		
				Ca	Mg	Na	SO ₄	Ca	Mg	Na	Ca	Mg	Na	SO ₄	Sum'n
Eroded Profile (Grassed over).															
349	A ₂	0"-2"	flaky, little structure	0.6	0.4	0.2	none	5.9	4.0	0.4	none	10.3	10.2		
350	B ₁	2"-14"	small, strong columns	0.6	0.4	0.3	trace	12.0	8.8	0.4	none	21.2	20.8		
351	B ₂	14"-	lime and salts. columnar	2.4	2.1	0.8	trace	90.0	17.0	0.6	none	107.6	77.5		
Non-eroded Profile. (15' distant)															
346	A	0"-3"	laminated, little structure	0.5	0.2	0.3	trace	8.9	4.5	0.4	none	13.8	15.8		
347	B ₁	3"-11"	small columns crumbles	0.6	0.6	0.4	trace	13.0	10.2	0.4	none	23.6	23.2		
348	B ₂	11"-	columnar, heavy lime horizon	2.8	1.5	0.5	trace	79.0	13.8	0.4	trace	93.2	55.0		

Tabel IIA. Group V. - Percentage Comparison of Water-soluble, Exchangeable, and Total Extracted Bases and M. E. of Total Extracted Bases of Adjacent Eroded and Non-eroded Weakly Solonized Glacial Loam Profiles.

Sample No.	Hori- zon	Percentage Milligram Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
349 350 351	A2 B1 B2	50 46 45	33 31 40	17 23 15	57 57 84	39 41 15	4 2 1	57 56 82	38 41 17	5 3 1	6.5 12.6 92.4	4.4 9.2 19.1	0.6 0.7 1.4	
346 347 348	A B1 B2	50 38 58	20 38 31	30 24 11	64 55 85	33 43 14	3 2 1	63 54 83	32 43 16	5 3 1	9.4 13.6 81.8	4.7 10.8 15.3	0.7 0.8 0.9	
		99												

Table II. Group VI. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Adjacent Eroded and Non-eroded Solonized Silt Loam Profiles. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents				Exchange Constituents				Base Exchange Capacity	
				Bases as m. e.			Mgms.	Bases as m. e.			Mgms.		
				Ca	Mg	Na	SO4	Ca	Mg	Na	SO4		
				m. e.				m. e.					
Eroded Profile #1.													
360	B1	0"-4"	single grain structure lime and salts	0.6	0.7	2.7	none	8.6	14.6	3.2	none	26.4	25.3
361	B2	4"-		18.4	6.8	8.3	1919	60.0	7.8	0.7	trace	68.5	66.0
Non-eroded Profile (at edge of erosion) #2.													
355	A1	0"-5"	little structure flaked off	0.6	0.2	0.7	none	5.8	2.9	0.4	none	9.1	11.0
358	A2	--	"round-	1.1	0.4	1.0	none	6.3	1.9	0.3	none	8.5	8.7
359	B0	--	top" tips	0.4	0.2	1.2	none	7.3	3.7	2.3	none	13.3	13.5
356	B1	5"-8"	strong	1.1	0.3	2.4	none	15.6	9.6	4.0	none	29.2	26.0
			"round-tops columnar, lime										
357	B2	8"-		2.1	0.2	2.4	none	109.0	5.5	0.6	none	115.1	55.0

Table IIA. Group VI. - Percentage Comparison of Water-Soluble, Exchangeable and Total Extracted Bases and m. E. of Total Extracted Bases of Adjacent Eroded and Non-eroded Solonized Silt Loam Profiles.

Sample No.	Hori- zon	Percentage Milligram Equivalents									Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
360	B ₁	15	18	67	33	55	12	30	50	20	9.2	15.3	5.9
361	B ₂	55	20	25	88	11	1	77	14	9	78.4	14.6	9.0
Eroded Profile #1													
Non-eroded Profile #1 (at edge of Erosion).													
355	A ₁	40	13	47	64	32	4	60	29	11	6.4	3.1	1.1
358	A ₂	44	16	40	74	22	4	67	21	12	7.4	2.3	1.3
359	B ₀	22	11	67	55	28	17	51	26	23	7.7	3.9	3.5
356	B ₁	29	8	63	53	33	14	51	30	19	16.7	9.9	6.4
357	B ₂	45	4	51	95	4	1	92	5	3	111.1	5.7	3.0

The following is a list of the names of the persons who have been
 elected to the office of the Board of Directors of the
 City of New York for the year 1900.

Ward		Name		Address		Occupation		Term	
1	1	John A. Smith	John A. Smith	123 4th St.	123 4th St.	Merchant	Merchant	1900	1901
	2	James B. Jones	James B. Jones	456 5th St.	456 5th St.	Lawyer	Lawyer	1901	1902
	3	William C. Brown	William C. Brown	789 6th St.	789 6th St.	Doctor	Doctor	1902	1903
	4	Robert D. White	Robert D. White	101 7th St.	101 7th St.	Engineer	Engineer	1903	1904
2	1	Charles E. Black	Charles E. Black	234 8th St.	234 8th St.	Teacher	Teacher	1904	1905
	2	Thomas F. Green	Thomas F. Green	567 9th St.	567 9th St.	Farmer	Farmer	1905	1906
	3	Henry G. Hall	Henry G. Hall	890 10th St.	890 10th St.	Banker	Banker	1906	1907
	4	George H. King	George H. King	112 11th St.	112 11th St.	Artist	Artist	1907	1908
3	1	Edward J. Lee	Edward J. Lee	345 12th St.	345 12th St.	Writer	Writer	1908	1909
	2	Frank L. Miller	Frank L. Miller	678 13th St.	678 13th St.	Musician	Musician	1909	1910
	3	John M. Davis	John M. Davis	901 14th St.	901 14th St.	Scientist	Scientist	1910	1911
	4	William N. Wilson	William N. Wilson	123 15th St.	123 15th St.	Businessman	Businessman	1911	1912

Table II. Group VI. (Cont.) - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Adjacent Eroded and Non-eroded Solonized Silt Loam Profiles. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents				Exchange Constituents				Base Exchange Capacity	
				Bases as m. e.		Mgms.	Bases as m. e.		mgms.				
				Ca	Mg		Na	SO ₄		Ca	Mg	Na	SO ₄
				Adjacent Non-eroded Profile #3									
352	A	0"-5"	flaky to columnar	0.4	0.2	0.4	none	8.8	3.1	0.3	none	12.2	14.8
353	B ₁	5"-10"	weakly solonized small columns	0.7	0.1	1.1	none	24.6	10.9	0.6	none	36.1	35.0
354	B ₂	10"-	lime deposition	2.4	0.7	1.2	none	87.0	10.1	0.4	none	97.5	73.0
Adjacent Eroded Profile in Cultivation #4.													
362	A	0"-4"	plow depth, light grey brown	0.4	0.2	0.7	trace	10.7	4.4	0.4	none	15.5	15.6
363	B ₁	4"-7"	strong "round-tops"	0.6	0.3	1.8	none	16.7	11.4	3.4	none	31.5	27.8
364	B ₂	7"-	lime and salts	3.4	0.7	4.0	trace	75.9	12.4	1.2	trace	89.5	66.0

Table IIA. Group VI. (Cont.). - Percentage Comparison of Water-Soluble, Exchangeable, and Total Extracted Bases, and M. E. of Total Extracted Bases of Adjacent Eroded and Non-eroded Solonized Silt Loam Profiles.

Sample No.	Hori- zon	Percentage Milligrams Equivalents									Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
Adjacent Non-eroded Profile													
352	A	40	20	40	72	25	3	70	25	5	9.2	3.3	0.7
353	B1	37	5	58	68	30	2	67	29	4	25.3	11.0	1.7
354	B2	56	16	28	89	10	1	88	10	2	89.4	10.8	1.6
Adjacent Erosion (in Cultivation).													
362	A	31	15	54	69	28	3	66	27	7	11.1	4.6	1.1
363	B1	22	11	67	53	36	11	51	34	15	17.3	11.7	5.2
364	B2	42	9	49	85	14	1	81	14	5	79.3	13.1	5.2

Table II. Group VII. - Comparison of Water-Soluble Salts, Exchange Constituents and Base Exchange Capacity of near-eroded and Non-eroded Solonized Glacial Loam Profiles. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents					Base Exchange Capacity	
				Bases as m. e.			Bases as m. e.						
				Mgms.			Mgms.						
				Ca	Mg	Na	SO4	Ca	Mg	Na	SO4	Sum'n	m. e.
Non-eroded Profile (4' from erosion)													
480	A1	0"-5"	loose	0.6	0.3	0.3	none	8.8	3.6	0.4	none	12.8	13.2
481	A2	5"-6"	slight flaking	0.7	0.4	0.3	none	9.2	4.3	0.4	none	13.9	13.6
482	B1	6"-10"	weakly solonized columnar lime,	1.7	0.9	1.0	none	30.5	11.0	0.4	none	41.9	34.4
483	B2	10"-15"	columnar lime,	3.0	1.7	1.4	none	80.0	11.2	0.4	none	91.6	67.0
484	B3 or C	20"-24"	columnar lime, black	1.9	0.8	2.6	none	45.0	13.0	0.7	none	58.7	31.4
Non-eroded Profile (40' from erosion)													
485	A1	0"-4"	loose, fluffy	0.7	0.8	0.2	none	7.9	4.3	0.4	none	12.6	13.6
486	A2	4"-8"	cloddy	1.1	0.8	0.3	none	7.2	4.5	0.3	none	12.0	13.8
487	B1	8"-12"	weak columns	0.5	0.7	0.5	none	10.3	6.6	0.4	none	17.3	18.8
488	B2	12"-15"	more cloddy	0.7	0.7	0.8	none	9.7	6.6	0.4	none	16.7	16.6
489	B3	15"-19"	cloddy	0.3	0.6	1.0	none	9.4	8.1	1.1	none	18.6	17.4
490	B4	19"-	lime	1.6	1.0	3.2	none	54.4	12.0	0.6	none	67.0	33.0

Table IIA. Group VII. - Percentage Comparison of Water Soluble, Exchangeable, and Total Extracted Bases and M. E. of Total Extracted Bases of Near-eroded and Non-eroded Solonized Glacial Loam Profiles.

Sample No.	Hori- zon	Percentage Milligrams Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
480	A1	50	25	25	69	28	3	67	28	5	9.4	3.9	0.7	
481	A2	50	29	21	66	31	3	64	31	5	9.9	4.7	0.7	
482	B1	47	25	28	73	26	1	71	26	3	32.2	11.9	1.4	
483	B2	49	28	23	87	12	1	85	13	2	83.0	12.9	1.8	
484	B or C	36	15	49	77	22	1	73	22	5	46.9	13.8	3.3	
Non-eroded Profile (40' from erosion)														
485	A1	41	47	12	63	34	3	60	36	4	8.6	5.1	0.6	
486	A2	50	36	14	60	37	3	59	37	4	8.3	5.3	0.6	
487	B1	29	42	29	60	38	2	57	38	5	10.8	7.3	0.9	
488	B2	32	32	36	58	40	2	55	39	6	10.4	7.3	1.2	
489	B3	16	32	52	50	44	6	47	43	10	9.7	8.7	2.1	
490	B4	28	17	55	81	18	1	77	18	5	56.0	13.0	3.8	

Table II. Group VIII. - Comparison of Water-Soluble Salts, Exchange Constituents and Base Exchange Capacity of Adjacent Eroded and Non-eroded Solonized Glacial Loam Profiles. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents				Exchange Constituents				Base Exchange Capacity	
				Bases as m. e.				Bases as m. e.				m. e.	
				mgms.		mgms.		mgms.		mgms.		mgms.	
				Ca	Mg	Na	SO ₄	Ca	Mg	Na	SO ₄	Sum'n	CaCl ₂
428	A	0"-1"	residual	0.4	0.4	0.7	none	7.6	4.3	0.4	none	12.3	19.0
429	B ₁	1"-5"	Al & A ₂ strong "round-tops"	0.5	1.0	3.5	none	20.5	10.5	1.2	none	32.2	29.0
430	B ₂	6"-9"	lime, columnar parent	1.3	1.4	5.2	139	58.0	10.9	0.8	none	69.7	46.0
431	C	9"-	shale	5.8	6.6	8.4	783	60.1	12.6	0.6	trace	73.3	31.0
423	A ₁	0"-5"	weak columns	0.7	0.3	0.3	none	6.5	2.5	0.3	none	9.3	13.8
424	A ₂	5"-6"	ashy	0.8	0.5	0.4	none	6.3	3.2	0.3	none	9.8	11.6
425	B ₁	6"-10"	no "round-tops"	0.7	0.8	1.0	none	17.8	8.3	0.4	none	26.5	25.4
426	B ₂	10"-14"	weakly solonized columnar, lime	2.2	1.2	1.6	none	48.8	9.0	0.4	none	58.8	41.3
427	C	16"-	salts, waxy	4.6	1.9	3.6	trace	46.5	12.4	4.0	trace	62.9	42.8

Table IIA. Group VIII. - Percentage Comparison of Water-soluble, Exchangeable, and Total extracted Bases and ^m. E. of Total Extracted Bases of Adjacent Eroded and Non-eroded Solonized Glacial Loam Profiles.

Sample No.	Hori- zon	Percentage milligrams Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases				Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
		Eroded Profile												
428	A	27	27	46	62	35	3	58	34	8	8.0	4.7	1.1	
429	B ₁	10	20	70	64	32	4	56	31	13	21.0	11.5	4.7	
430	B ₂	16	18	66	83	16	1	76	16	8	59.3	12.3	6.0	
431	C	28	32	40	82	17	1	70	20	10	65.9	19.2	9.0	
Non-eroded Profile (4' distant)														
423	A ₁	54	23	23	70	27	3	68	26	6	7.2	2.8	0.6	
424	A ₂	47	29	24	64	33	3	62	32	6	7.1	3.7	0.7	
425	B ₁	28	32	40	67	31	2	64	31	5	18.5	9.1	1.4	
426	B ₂	44	24	32	84	15	1	81	16	3	51.0	10.2	2.0	
427	C	45	19	36	74	20	6	70	20	10	51.1	14.3	7.6	

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Table II. Group IX. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Adjacent Non-eroded Solonized and Non-solonized Alluvial Sandy Loam Profiles. (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents					Base Exchange Capacity	
				Bases as m. e.			Bases as m. e.						
				Mgms.			Mgms.						
				Ca	Mg	Na	Ca	Mg	Na	SO ₄	Sum'n		CaCl ₂
575	A ₁	0"-8"	loose, sandy	0.2	0.2	0.4	3.8	1.3	0.6	none	5.7	6.8	
576	A ₂	8"-9"	loose, leached	0.2	0.2	0.5	2.5	1.0	0.6	none	4.1	4.4	
577	B ₁	9"-13"	strong "round-tops".	0.4	0.6	1.2	3.6	7.7	2.1	none	13.4	14.0	
578	B ₂	13"-16"	cloddy structure	0.4	0.6	2.9	11.1	3.2	1.0	none	15.3	16.8	
579	B ₃	16"-24"	little structure	13.4	7.5	5.5	80.0	47.0	0.9	none	127.9	22.4	
580	C	24"-	lime black shale	3.9	1.7	12.3	62.4	17.4	5.3	354	85.1	54.6	
581	A	0"-12"	vertical cleavage	Non-solonized Profile (50' from above).									
582	--	12"-26"	loose sand	0.3	0.2	0.2	7.6	2.1	0.5	none	10.2	9.8	
583	--	26"-36"	compact sand	0.2	0.2	0.2	5.0	1.7	0.5	none	7.2	6.0	
584	--	40"-	loose sand	0.2	0.1	0.3	8.5	3.4	0.5	none	12.4	9.4	
				0.2	0.1	0.3	5.8	2.6	0.6	none	9.0	7.8	

Table IIA. Group IX. - Percentage Comparison of Water-Soluble, Exchangeable, and Total Extracted Bases and m. E. of Total Extracted Bases of Adjacent Non-eroded Solonized and Non-solonized Alluvial Sandy Loam Profiles.

Sample No.	Horizon	Percentage Milligrams Equivalents									mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases		
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na
575	A1	25	25	50	67	23	10	62	23	15	4.0	1.5	1.0
576	A2	22	22	56	61	24	15	54	24	22	2.7	1.2	1.1
577	B1	18	27	55	27	57	16	26	53	21	4.0	8.3	3.3
578	B2	10	16	74	73	21	6	60	20	20	11.5	3.8	3.9
579	B3	51	28	21	62	37	1	61	35	4	93.4	54.5	6.4
580	C	22	10	68	73	21	6	64	19	17	66.3	19.1	17.6
Non-solonized Profile (50' from above)													
581	A	42	29	29	74	21	5	72	21	7	7.9	2.3	0.7
582	--	33	33	33	69	24	7	67	24	9	5.2	1.9	0.7
583	--	33	17	50	69	27	4	67	27	6	8.7	3.5	0.8
584	--	33	17	50	64	29	7	63	28	9	6.0	2.7	0.9

Table III. Analyses of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity in a Non-eroded, Strongly Solonized Glacial Loam Profile.
(per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents				Exchange Constituents				Base Exchange Capacity	
				Bases as m. e.			Mgms. SO ₄	Bases as m. e.			mgms. SO ₄		
				Ca	Mg	Na		Ca	Mg	Na			
													Sum'n
Non-eroded Profile (Strongly Solonized).													
730	A1	0"-4"	fluffy, little structure	0.5	0.3	0.5	trace	8.4	2.2	0.4	trace	11.0	29.4
731	A2 B0	4"-7"	flaky tips of	0.4	0.2	0.7	trace	5.8	1.8	1.5	none	9.1	18.4
732		7"-8"	"round-tops"	0.4	0.5	1.2	none	11.5	5.3	2.9	none	19.7	22.4
733	B1	8"-12"	strong "round-tops"	0.4	0.2	1.4	none	14.2	5.2	3.2	none	23.6	25.2
734	B2 B3	12"-17"	granular	0.4	0.4	1.7	none	15.6	7.1	3.2	none	25.9	25.6
735		17"-22"	porous, some columns	0.4	0.4	1.7	trace	12.5	5.5	2.9	none	20.9	20.2
736	B4	22"-36"	clay shale pockets	0.6	0.2	1.6	trace	14.3	5.4	3.3	none	23.0	21.4
737	B5	36"-60"	compact to sandstone	0.4	0.2	2.6	trace	9.4	4.4	1.7	180	15.5	13.7
738	C	60"-	parent sandstone	0.4	0.3	4.2	trace	17.2	4.0	0.9	trace	22.1	--

Table IIIA. Percentage Analyses of Water-Soluble, Exchangeable, and Total Extracted Bases and M. E. of Total Extracted Bases in a Non-eroded Strongly Solonized Glacial Loam Profile.

Sample No.	Horizon	Percentage Milligrams Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
730	A1	38	24	38	76	20	4	73	20	7	8.9	2.5	0.9	
731	A2	31	15	54	64	20	16	60	19	21	6.2	2.0	2.2	
732	B0	19	24	57	58	27	15	54	27	19	11.9	5.8	4.1	
733	B1	20	10	70	60	26	14	57	25	18	14.6	6.4	4.6	
734	B2	16	16	68	60	27	13	57	26	17	16.0	7.5	4.9	
735	B3	16	16	68	60	26	14	55	25	20	12.9	5.9	4.6	
736	B4	25	8	67	62	23	15	59	22	19	14.9	5.6	4.9	
737	B5	13	6	81	61	28	11	52	25	23	9.8	4.6	4.3	
738	C	8	6	86	78	18	4	65	16	19	17.6	4.3	5.1	

Table IV. Group I. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of "Normal (Bindloss) and Solonized (Bingville) Silt Loam Area Profiles (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents				Exchange Constituents				Base Exchange Capacity	
				Bases as m. e.			Mgms.	Bases as m. e.			Mgms.		
				Ca	Mg	Na	SO ₄	Ca	Mg	Na	SO ₄		Sum'n CaCl ₂
Normal Silt Loam Area (Bindloss)													
330	A ₁	0"-4"	platy, friable	0.7	0.2	0.2	none	14.3	4.2	0.3	none	18.8	19.6
331	B ₁	4"-9"	small columns	0.8	0.2	0.2	none	16.8	6.2	0.3	none	23.2	22.8
332	B ₂	9"-13"	larger columns	1.1	0.3	0.3	none	16.5	5.8	0.4	none	22.7	20.0
333	B ₃	13"-	lime	2.0	1.1	0.2	none	96.0	8.6	0.4	none	105.0	83.8
Very Weakly Solonized Silt Loam (Bingville)													
352	A	0"-5"	flaky to columnar	0.4	0.2	0.4	none	8.8	3.1	0.3	none	12.2	14.8
353	B ₁	5"-10"	weakly solonized small columns	0.7	0.1	1.1	none	24.6	10.9	0.6	none	36.1	35.0
354	B ₂	10"-	lime deposit	2.4	0.7	1.2	none	87.0	10.1	0.4	none	97.5	73.0

Table IVA. Group I. - Percentage Comparison of Water-Soluble, Exchangeable and Total Extracted Bases and M. E. of Total Extracted Bases of Normal (Bindloss) and Solonized (Bingville) Glacial Silt Loam Area Profiles.

Sample No.	Hori- zon	Percentage Milligrams Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
		Normal Silt Loam Area (Bindloss)												
330	A1	64	18	18	76	22	2	75	22	3	15.0	4.4	0.5	
331	B1	66	17	17	72	27	1	72	26	2	17.6	6.4	0.5	
332	B2	64	18	18	72	26	2	72	25	3	17.6	6.1	0.7	
333	B3	61	33	6	91	8	1	90	9	1	98.0	9.7	0.6	
Very Weakly Solonized Silt Loam (Bingville)														
352	A	40	20	40	72	25	3	70	25	5	9.2	3.3	0.7	
353	B1	37	5	58	68	30	2	67	29	4	25.3	11.0	1.7	
354	B2	56	16	28	89	10	1	88	10	2	89.4	10.8	1.6	

Table IV. Group II. - Comparison of Water-Soluble Salts, Exchange Constituents and Base Exchange Capacity of Normal (Provost) and Solonized (Brooks) Glacial Silt and Silty Loam Area Profiles (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents			Exchange Constituents			Base Exchange Capacity.			
				Bases as m. e.			Bases as m. e.				Mgms. SO ₄		
				Ca	Mg	Na	Ca	Mg	Na				
				Bases as m. e.			Mgms.			m. e.			
				Ca	Mg	Na	SO ₄	Ca	Mg	Na	SO ₄	Sum'n	CaCl ₂
Silt Loam Profile in Normal Area (Provost)													
555	A	0"-6"	flaky, porous firm	0.9	0.3	0.2	none	15.7	5.1	0.4	none	21.2	22.2
556	B ₁	6"-12"	massive to columnar	1.0	0.4	0.2	none	14.3	6.2	0.4	none	20.9	19.5
557	B ₂	12"-	columnar, lime horizon	2.1	1.2	0.3	none	90.4	15.0	0.5	trace	105.9	77.2
Silty Loam Profile in Solonized Area (Brooks)													
485	A ₁	0"-4"	loose, fluffy	0.7	0.8	0.2	none	7.9	4.3	0.4	none	12.6	13.6
486	A ₂	4"-8"	cloddy	1.1	0.8	0.3	none	7.2	4.5	0.3	none	12.0	13.8
487	B ₁	8"-12"	some columns	0.5	0.7	0.5	none	10.3	6.6	0.4	none	17.3	18.8
488	B ₂	12"-15"	more cloddy	0.7	0.7	0.8	none	9.7	6.6	0.4	none	16.7	16.6
489	B ₃	15"-19"	cloddy	0.3	0.6	1.0	none	9.4	8.1	1.1	none	18.6	17.4
490	B	19"-	lime horizon	1.6	1.0	3.2	none	54.4	12.0	0.6	none	67.0	33.0

Table IVA. Group II. - Percentage Comparison of Water-soluble, Exchangeable and Total Extracted Bases and ^m. E. of Total Extracted Bases of Normal (Provost) and (Brooks) Solonized Silt and Silty Loam Area Profiles.

		Percentage Milligrams Equivalents										Mgm. Equivalents		
Sample No.	Hori- zon	Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
Silt Loam Profile in Normal Area. (Provost)														
555	A	64	22	14	74	24	2	73	24	3	16.6	5.4	0.6	
556	B ₁	63	25	12	68	30	2	68	29	3	15.3	6.6	0.6	
557	B ₂	59	33	8	85	14	1	84	15	1	92.5	16.2	0.8	
Silty Loam Profile in Solonized Area (Brooks)														
485	A ₁	41	47	12	63	34	3	60	36	4	8.6	5.1	0.6	
486	A ₂	50	36	14	60	37	3	59	37	4	8.3	5.3	0.6	
487	B ₁	29	42	29	60	38	2	57	38	5	10.8	7.3	0.9	
488	B ₂	32	32	36	58	40	2	55	39	6	10.4	7.3	1.2	
489	B ₃	16	32	52	51	43	6	47	43	10	9.7	8.7	2.1	
490	B ₄	28	17	55	81	18	1	77	18	5	56.0	13.0	3.8	

Table V. - Comparison of Water-soluble Salts, Exchange Constituents and Base Exchange Capacity of Normal Area (Brownfield) and Heavily Solonized Area (Sullivan Lake). Glacial Loam Profiles (per 100 grams of air-dry soil).

Sample No.	Horizon	Depth	Horizon Description	Water Soluble Constituents		Exchange Constituents					Base Exchange Capacity		
				Bases as m. e. Mgms.		Bases as m. e. Mgms.							
				Ca	Mg	Na	SO ₄	Ca	Mg	Na	SO ₄	Sum'n CaCl ₂	
719	A ₁	0"-5"	cloddy, firm	0.7	0.2	0.2	none	11.7	4.0	0.3	none	16.0	18.6
720	A ₂	5"-10"	strong columnar	0.6	0.2	0.3	none	11.2	4.4	0.3	none	15.9	16.0
721	B ₁	10"-18"	cloddy	0.4	0.1	0.3	none	7.6	3.5	0.3	none	11.4	10.8
722	B ₂	20"-28"	porous, grey	0.4	0.2	0.3	none	8.9	4.6	0.3	none	13.8	12.2
723	B ₃	30"-	friable, lime	1.8	0.6	0.3	none	60.0	8.4	0.3	none	68.7	46.0
730	A ₁	0"-4"	little structure	0.5	0.3	0.5	trace	8.4	2.2	0.4	trace	11.0	29.4
731	A ₂	4"-7"	flaky	0.4	0.2	0.7	trace	5.8	1.8	1.5	none	9.1	18.4
733	B ₁	8"-12"	massive to columnar	0.4	0.2	1.4	none	14.2	6.2	3.2	none	23.6	25.2
735	B ₂	17"-22"	porous, columns	0.4	0.4	1.7	trace	12.5	5.5	2.9	none	20.9	20.2
736	B ₃	22"-36"	shale pockets	0.6	0.2	1.6	trace	14.3	5.4	3.3	none	23.0	21.4

Table VA. - Percentage Comparison of Water-soluble, Exchangeable and Total Extracted Bases and M. E. of Total Extracted Bases of Normal Area (Brownfield) and Heavily Solonized Area (Sullivan Lake) Glacial Loam Profiles.

Sample No.	Horizon	Percentage Milligrams Equivalents										Mgm. Equivalents		
		Water Soluble Bases			Exchange Bases			Total Extracted Bases			Total Extracted Bases			
		Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	Ca	Mg	Na	
Normal Profile (Brownfield Area)														
719	A1	64	18	18	73	25	2	72	25	3	12.4	4.2	0.5	
720	A2	55	18	27	70	28	2	69	27	4	11.8	4.6	0.6	
721	B1	50	12	38	67	31	2	66	29	5	8.0	3.6	0.6	
722	B2	45	22	33	65	33	2	63	33	4	9.3	4.8	0.6	
723	B3	67	22	11	87	12	1	87	12	1	61.8	9.0	0.6	
Solonized Profile (Sullivan Lake Area)														
730	A1	38	24	38	76	20	4	73	20	7	8.9	2.5	0.9	
731	A2	31	15	54	64	20	16	60	19	21	6.2	2.0	2.2	
733	B1	20	10	70	60	26	14	57	25	18	14.6	6.4	4.6	
735	B2	16	16	68	60	26	14	55	25	20	12.9	5.9	4.6	
736	B3	25	8	67	62	23	15	59	22	19	14.9	5.6	4.9	

Total extracted base percentages show that the proportion of Na is consistently higher in the solonized profiles.

The significant feature of this group comparison is the low amounts of soluble bases and exchange Na present in the more normal profile. This could mainly be attributed to differences in drainage, either being slightly higher or by having a more pervious subsoil.

Table II. Group IV.

These two profiles which were analyzed and the results given in this comparison were selected within a few miles of each other, since the first profile occurred in a normal soil area. Both surface soils are a fine sandy loam in texture. The purpose of this comparison was to determine if any marked differences in base content and proportion occurred in a badly solonized profile, and in a normal profile taken from a normal area. The profiles were selected as close to each other as was possible in this case. It should be noted that the normal profile is much deeper than the solonized profile.

The water soluble analyses indicate that the content of water soluble Na is greater in the solonized profile, with higher concentrations much closer to the soil surface. In the normal area profile, no great accumulation of water soluble Na occurs until the parent shales are encountered at 4 feet. The presence of the sulphate wherever Na concentrations occur, suggest the presence of considerable Na_2SO_4 . In the lower horizons of both profiles, some gypsum appears to be present.

Exchangeable base analyses also show higher Na in the

solonized profile, with the greatest concentrations occurring in the solonized B₁ horizon, whereas very small amounts of Na occur in the normal profile. The exchange divalent bases in the normal soil are greater than in the solonized profile, but a portion of this Ca and Mg actually existed in the soluble form, probably as the carbonate. (Note the discrepancies in the results of the last two columns of the table for the B₂ and C horizons of the normal profile). In the solonized profile, such concentrations of carbonate apparently do not occur, since only minor differences exist in the base exchange capacity analyses for that profile. No base unsaturation is noted in either profile.

Table A shows that water soluble Na occurs in greater proportions in the solonized profile, especially in the upper horizons. The percentage of exchange bases shows the very low proportion of exchange Na present in the normal soil (1 to 2 per cent) whereas it is several times this percentage in the solonized profile. The percentages of total extracted bases also illustrates the greater relative proportion of Na in the solonized profile.

The conclusions from this comparison are that both water soluble and exchangeable Na content of a solonized soil is greater in both amounts and proportions. Greater concentrations are also closer to the surface than that found in a normal profile taken in the same general area. This is probably a result of poor drainage and a relatively impervious B₁ horizon which prevents percolation of water. If any significant quantity of Na was originally present in the normal soil, it appears to

have been removed, probably by percolating water to other areas. It seems logical to assume that this displaced Na (due to its solubility) has finally accumulated on lower, more level areas, which is the type of topography upon which solonization and erosion appear to have maximum development.

Table II Group V.

The two profiles in this comparison were selected within a few feet of each other in a glacial loam area. It is important to note that this area is rolling topography, solonization is very weakly developed, and erosion spots are few and largely grassed over.

Little or no significant differences exist in these two profiles, and the eroded profile appears to be almost normal. Differences in total and relative proportion of soluble bases might be attributed to sampling and analytical error. Sodium content, both in soluble and exchangeable bases is very low and the divalent bases are dominant. Low sulphate content and discrepancies in total exchange capacity indicate the abundance of carbonates in the B₂ horizon of both profiles.

This profile comparison in rolling topography supports the assumption that good drainage tends to decrease the content of water soluble, and eventually the content of the exchange, sodium. The abundance of calcium carbonate also appears to be important in converting the solonized to a normal profile.

Table II. Group VI.

The comparison presented in this table consists of analyses on four profiles, one of which was selected from an eroded spot in cultivation. The profiles were all selected within a 25

yard radius, but on slightly different levels and with varying degrees of profile development. The topography is undulating and the soil type is a solonized silt loam.

The most significant differences between these four profiles is that of profile #3 from the other three profiles. This is a non-eroded, very slightly solonized profile, a short distance from any erosion. Smaller differences in bases exist among the other three profiles.

Water soluble analyses indicate that Na is comparatively high in the more solonized profiles #1, #2, and #4. In profiles #1 and #4, which are both eroded, a high concentration of Na_2SO_4 and gypsum is apparently present in the B_2 horizon. (Samples #361, and #364). This relatively high concentration of the sulphate appears to be a common occurrence in the B_2 horizons of eroded profiles, and seems to be a result of the impermeable B_1 horizon developed. Any precipitation occurring on these eroded spots does not pass through the B_1 but is evaporated, after lying on the eroded surface for some time. The absence of leaching through this horizon, results in the accumulation of the sulphates relatively close to the surface --otherwise they would be leached to a much greater depth. It is seen that the water soluble Na content of profile #3 is quite low in comparison to the other three profiles.

The exchange base analyses also show that the content of Na is greater, especially in the B_1 horizons, in the three more solonized profiles, although in all cases the exchangeable divalent bases are much in excess of the exchange Na.

Total base exchange capacity results (see last two columns of table) indicate that carbonates occur in considerable amounts in the lower horizons of all four profiles.

Table A shows that water soluble sodium occurs in slightly greater quantities in profiles #1, #2, and #4, whereas it is less important in the third and less solonized profile. Water soluble Na content of the three profiles may be important, in that Na may directly displace the divalent bases from the exchange complex, and thus increase the amounts of exchange Na. However, the water soluble Na would probably have to occur in much greater excess than it does here, to have such replacement occur. The exchangeable Na, while it is proportionally much lower than the water soluble Na, is still of considerable importance especially in the B₁ horizons in the three more solonized profiles. The third profile again shows the least proportion of this base. Total extracted base percentages give much the same picture. It should be emphasized that in all the profiles in this comparison the greater proportions of Na occur in the B₁ horizons.

The conclusions of this comparison are that relative differences in base content and proportion occur in profiles selected within a very small radius. Sodium appears to be relatively more important in the solonized profiles, and there appears to be a direct relationship between Na content and structural development. An accumulation of the sulphates of Ca, Mg and Na is noted in the B₂ horizons of the eroded profiles. In the case of the cultivated eroded solonized profile,

there has been no significant decrease in soluble Na in any horizon. Surface cultivation has not, as yet, produced any marked decrease in Na content in the lower horizons.

Table II. Group VII.

This comparison consists of two profiles, neither of them being eroded. One profile was selected 4 feet from an erosion spot, whereas the second was approximately 40 feet distant and well removed from any erosion. Both profiles were weakly solonized, although solonization was more marked in the profile near the erosion. The region was an undulating glacial loam. The object of the comparison was to determine if any great difference in base content occurred between these two profiles on the same level in regard to proximity of erosion.

The analyses are in harmony with previous results obtained on weakly solonized profiles, situated on the same general level. Water soluble Na is low in both profiles, with a gradual increase with depth. Water soluble Ca and Mg occur in about normal quantities, and sulphates do not appear to be present in any great amount. It may be said in general, that the amounts of water soluble salts in these profiles are very small.

The quantities of exchangeable Na are also very low with little increase with depth of profile, whereas the divalent bases have increased considerably. The base exchange capacity analysis indicate that carbonates occur in both profiles in considerable quantities, especially in the lower horizons. Base unsaturation apparently does not occur.

Table A indicates that water soluble Na becomes dominant

with respect to the divalent bases, only in the lowest horizons. This would indicate some leaching of soluble salts in these more weakly solonized profiles, with the removal of these salts from the upper horizons. The percentage of exchange Na is very low for a solonized soil, which could be expected from the low amounts of soluble Na salts present. Total extracted base percentages show that in general, Na constitutes only about 5 per cent of the three bases determined, which approaches the amount of Na found in normal soil profiles. The presence or absence of CaCO_3 is an important factor in converting solonized soils to the more normal profile.

The conclusions from this comparison are that a weakly solonized structure appears to be related to low Na content and proportion. Low soluble Na salts tend to produce low exchange Na in the complex. Evidently these two profiles are almost normal, both in structure and in base content, and nearness to erosion spots does not always indicate solonization characteristics occurring the soil.

Table II. Group VIII.

This comparison consists of two profiles, one eroded and the other non-eroded, selected 4 feet apart. The eroded profile shows well developed solonization characters, whereas the second profile is more weakly developed. The erosion or "slick spots" present, are about 5 inches deep and the soil is a glacial loam with undulating topography. The comparison was made to illustrate differences occurring in base content and proportion in relation to the degree of solonization of profiles within a small radius.

Water soluble Na occurs in much greater amounts in the eroded profile, increases of Na with depth occurring in both profiles where it evidently occurs as the sulphate. The parent shales appear to contain considerable gypsum as well as water soluble Mg. It is noted that differences apparently exist in the solubility of the Na in these shales.

Exchangeable Na occurs in smaller amounts, but is more abundant in the upper horizons of the eroded profile, where leaching has evidently not been so great. The exchangeable divalent bases are greatly in excess of the exchange Na in both profiles. Total base exchange capacity analyses indicate an unsaturated condition in the A horizon of the eroded profile, and slight unsaturation may occur in the same horizon of the non-eroded profile. In the lower horizons, considerable amounts of carbonates appear to be present.

Table A shows that the percentage of soluble Na is much greater in the eroded profile, being dominant to the divalent bases in two of these horizons. As pointed out previously, this is probably the result of limited water percolation through the heavily solonized B₁ horizon. The proportion of exchange Na is low in both profiles, but total extracted base percentages show that Na is consistently higher in the eroded and more strongly solonized profile.

The conclusions of this comparison are that base unsaturation does occur in the A horizons of some solonized profiles, but evidently is not a constant character. The sodium content of the soil appears to be related to the degree of solonization. The removal of most of the A horizon in the eroded spots leads

to evaporation, rather than to the downward percolation of water through the soil. This probably causes greater amounts of soluble sodium salts to remain relatively close to the surface. Thus the amounts of exchange sodium tend to remain fairly constant and the B₁ horizons apparently retain their deflocculated and impermeable character. The shallow depths at which the parent shales occur with their apparent high Na content, possibly has been one factor in causing the original erosion.

Table II. Group IX.

This comparison consists of two profiles, one of which was located at the edge of an erosion spot, and showed pronounced solonized structure. The second was selected some 50 feet distant on the same level, and showed little structural development with a very sandy subsoil. The topography was undulating and the soil type is an alluvial sandy loam. Since the parent shales below the solonized profile occurred at 24 inches, this comparison was made to illustrate differences in solonization which apparently were due to an impervious subsoil occurring relatively close to the surface.

Water soluble Na occurs in much greater amounts in the solonized profile with high concentrations in the parent shales where it appears to occur largely as the sulphate. Considerable gypsum and water soluble Mg also occur in the B₃ horizon. The non-solonized profile has very small amounts of water soluble bases present, at least to depth of 40 inches, and leaching appears to have been extreme. Apparently the parent shales occur at much greater depths in this case. The exchange base

analyses also show more Na present in the solonized profile, though the divalent bases also occur in greater amounts, being dominant to the Na, especially in the parent shale. The amount of exchange base in all horizons of the non-solonized profile is relatively low. Total base exchange capacity analyses show the presence of extremely little carbonate, except in the B₃ and C horizons of the solonized profile. No base unsaturation in any horizon appears to be present.

Table A shows some differences in the two profiles as to the proportions of water soluble Na - it appears to be mainly a question of the differences in the quantity of bases present in the profiles. The percentages of exchange bases show a higher Na content in the upper horizons of the solonized profile, which is probably a result of the greater amounts of soluble Na salts present. The percentages of total extracted bases show that Na is consistently a relatively more important base in the solonized profile.

This comparison appears to be a case where the presence or absence of a slightly pervious subsoil relatively close to the surface has been a contributing factor in the formation of a solonized profile. The parent shale of the solonized profile is within 24 inches of the surface, and appears to be very high in sodium, whereas in the non-solonized profile nothing but loose sand is encountered at 40 inches. In the latter case, subsurface drainage has been excellent, resulting in the leaching of any original bases present and their subsequent deposition elsewhere. The slightly pervious parent shales below the solonized profiles prevented adequate drainage

with the result that the original bases were probably not leached away, but possibly have accumulated. This would offer one explanation for the high water soluble Na content of the solonized soil.

Table III.

This analysis is presented to illustrate the base content and their proportions in a heavily solonized profile of the Sullivan Lake region. The topography of the area is undulating and the soil is a glacial loam with parent sandstones at approximately 5 feet from the surface. The profile was characterized by a very strong solonetz development.

It is noted that the water soluble divalent bases remain consistently low throughout the profile, whereas the content of water-soluble Na consistently increases with depth, apparently occurring as the sulphate. No concentration of gypsum is noted. The exchangeable divalent bases do not occur in any great amounts, but are decidedly dominant to the exchange Na, though exchange Na is greater than the water soluble Na amounts. Total base exchange capacity analyses indicate that apparently considerable base unsaturation occurs in both the A₁ and A₂ horizons. These results also show that carbonates are practically absent in the profile, even in the lower horizons where they usually occur in large amounts.

Table A shows that the percentage of water soluble Na constitutes over half the water soluble bases throughout the profile except in the A₁ horizon, being decidedly dominant over the water soluble divalent bases. The percentage of

exchangeable Na is much lower, but still remains relatively large. Total extracted base percentages shows that Na constitutes approximately 20 per cent of the total bases extracted. This is a relatively high Na concentration, and probably is a considerable factor in the development of the strongly solonized profile. Total extracted bases show that both Ca and Na increase quite consistently with depth, whereas Ma appears to be variable in this regard and occurs in intermediate amounts.

Significant features in this profile are the unsaturated A horizons and the relative absence of Ca in the carbonate form. It would seem that the low CaCO_3 and appreciable Na content of this soil would tend to prevent the development of a normal profile.

It was thought that significant differences in either soluble or exchange base content or proportions might exist between the soils of normal area, and the more normal profiles located in solonized areas adjacent to heavily solonized profiles. It was necessary to compare profiles selected several miles apart, but an effort was made to obtain soils which were the same in texture. Two comparisons of this type were made.

Table IV. Group I.

The two profiles whose analyses are presented in this table, were of necessity selected some miles apart, the topography being undulating and the soil type a silt loam in both cases. The normal area profile was selected east of Bindloss, whereas the second, which was an extremely weakly solonized profile in a more heavily solonized area, was selected near Bingville.

The water soluble base analyses indicate that Na content is slightly higher in the solonized profile and increases with depth, which is not true of the normal area profile. The exchange base analyses indicate that the solonized area profile is not essentially different in content or proportion of exchange bases than from soils of normal areas. Total base exchange capacity results show that no unsaturation appears to be present, and that the carbonates occur in considerable quantities in the lower horizons of both profiles.

Table A shows that the percentage of water soluble Na is distinctly greater in the solonized area profile, but the water soluble divalent bases are dominant except in the B₁ horizon. The percentages of exchange bases indicate that Na constitutes a very small proportion of these bases in both profiles. Percentages of total extracted bases illustrate that though Na does form a slightly greater proportion of the bases in the solonized area profile than in the normal area profile - the increase is not significant.

In general, differences in these two profiles are not significant, excepting the concentration of soluble sodium in the lower horizons of the solonized area profile. However, it must be kept in mind that very weakly solonized profiles such as the one compared above, are not characteristic of the more heavily solonized areas unless certain favorable conditions prevail, such as a topography allowing adequate drainage, or a pervious subsoil underlying such soils. On the whole the soil profiles of these areas show much stronger solonization

features, and as was previously pointed out, a higher content of sodium is a character of these profiles. This comparison does show that soils lacking the characteristic solonetz profile development even where present in solonized areas, do not differ materially either in quantity or proportion of bases from soils of normal areas, although the quantity of water soluble sodium in the lower horizons tends to be greater.

Table IV. Group II.

The two profiles in this comparison were selected near Provost and near Brooks respectively. The normal area profile from Provost is a silt loam, whereas the very weakly solonized profile from Brooks is a silty loam.

As in the previous group comparison, the main difference in the base content of the two profiles is the slightly greater amount of Na, with the attendant increase with depth in the solonized area profile. The content of water soluble divalent bases appears to be approximately the same. No significant differences occur in the content or proportion of exchangeable bases. Total base exchange capacity analyses indicate no unsaturation.

Table A shows that the percentage of water soluble Na to the divalent bases is greater in the solonized area profile, and Na here becomes dominant in the lower horizons. The exchange base percentages indicate Na to be consistently, though not significantly higher in proportion to the divalent area bases in the solonized area profile than is found in the normal profile. Total extracted base percentages give much the same picture.

From a consideration of these two profiles, it is apparent that very slightly higher water soluble sodium content and proportion to the divalent bases, is a feature of the most normal profiles in the solonized area when compared to profiles occurring in strictly normal soil areas.

Since only the most normal appearing profiles in the solonized area were selected for comparison, it would appear that soils from such areas have the higher sodium content due to the presence of the higher content of water soluble sodium, which has not been leached away probably as a result of the lower precipitation and the lack of adequate drainage in such areas.

Table V.

This table is presented to illustrate differences in base content and relative proportions occurring in a normal profile just outside the solonized area, and a strongly solonized profile in the Sullivan Lake region. The soil type in the two profiles is the same, and the topography in both cases is undulating.

The water soluble analyses indicate very little difference in either the amounts or relative proportions of the divalent bases present in the two profiles. However, it will be noted that the water soluble Na is consistently greater in the solonized area profile where it increases in quantity with increasing depth, whereas in the normal profile, the Na content is very low and remains practically constant throughout. The exchange base analyses present practically the same picture,

with the exception that there appears to be a considerable concentration of CaCO_3 in the lowest horizon of the normal area profile--which is not true of the solonized profile. Unsaturation is also evident in the latter profile.

Table A illustrates that the percentage of water soluble Na to the divalent bases is much greater in the solonized area profile, whereas it never becomes dominant in the normal profile. The exchangeable and total extracted base percentages show much the same relationship. Total extracted bases also emphasize the fact that Na occurs in much greater amounts in the solonized soils.

This comparison of two profiles located only a few miles apart indicate that Na appears to have a direct bearing on profile structure. The lack of CaCO_3 in the solonized horizon is probably a contributing factor to such structure development.

General Discussion

The results of this investigation show the vertical distribution of soluble, exchangeable and total extracted bases in various soil types occurring in several parts of southeastern Alberta. These profiles were selected mainly from the brown soil zone although a few were obtained from the dark brown soil zone. Total exchange capacity of the various horizons was also determined, but such results are not reliable in the lower B horizons.

Kelley and Brown (14) include soils whose replaceable Na amounts to almost 14 per cent of the exchangeable bases

present, in the neutral or slightly alkaline soil group. Since the greatest percentage of exchange Na found in any horizon of the soils studied was 21 per cent of the three major exchange bases, and is usually much lower, it would appear that the Alberta solonetzic soils would in general be included in this group. However, it should be remember that these soils do contain larger proportions of exchangeable Na to the divalent exchange bases than are present in the more normal soils of the world. In the three normal area profiles studied exchange Na did not exceed 3 per cent; Ca and Mg constituting 97 per cent of the three major exchange bases present. Kelley and Brown (14) report that in neutral or slightly alkaline soils of California, Russia and Holland studied, exchange Na averaged 8 per cent, 0 per cent and 6 per cent of the four main exchange bases present.

In the present study it was considered advisable to present the upper and lower limits of sodium extracted in each horizon of all the profiles studied. (The clay flat profile of Table I was omitted, since this profile is not representative of the solonized area and was the only heavy clay soil investigated). The extreme limits of sodium content are presented in milligram equivalents extracted per 100 grams of air-dry soil, and also as a percentage of the three major bases determined. The profiles included were divided into two main divisions; the solonized area profiles and the normal area profiles being considered as two distinct groups. Water soluble, exchangeable, and total extracted sodium ranges are presented, from twenty solonized area profiles, and from four

normal area profiles. (Actually one of the normal area profiles was located in the solonized area, but was in a strictly normal profile district.) This range of sodium is presented in Table VI.

Table VI.

In this table, the ranges of sodium for the C horizons of five solonized area profiles are given. However, these will not be considered in the comparison, since no such data was determined in the normal soil area. Also, the upper limits of exchangeable sodium in one profile showed 8.7 m.e. of sodium in the B₁ horizon, whereas the upper limit in the B₁ of all the rest of the solonized area profiles was 4.0 m.e. or lower. In a second B₁ horizon of the solonized area, due to low exchange calcium and magnesium present, the upper percentage limit of exchange sodium was 35 per cent, whereas the same horizon in all other solonized area profiles were not above 17 per cent. Obviously it would be misleading to include these amounts in the comparison, and they are placed in brackets, and are not included in the discussion. The limits given represent the extreme range of sodium in the profiles with the exception of the C horizons.

The range of the water soluble sodium in the solonized area is from 0.2 m.e. to 8.3 m.e., whereas the corresponding limits in the normal soil are 0.2 m.e. to 1.4 m.e. The percentage limits of water soluble sodium show much the same relation, those of the solonized area profiles varying from 11 to 80 per cent in comparison to the normal area limits of

Table VI. Range of amounts and proportions of sodium extracted in solonized area profiles and in normal area profiles

Horizon	Solonized Area Profiles		Normal Area Profiles	
	m.e. of Extracted	Na as % of Bases	m.e. of Extracted	Na as % of Bases
Water Soluble				
A ₁	0.2- 0.9	12-50	0.2-0.2	13-18
A ₂	0.2- 1.0	14-60	0.2-0.3	18-27
B ₁	0.3- 3.5	23-70	0.2-0.3	12-38
B ₂	0.5- 8.3	11-80	0.3-1.4	8-36
C	2.6-12.3	36-86	---	---
Exchangeable				
A ₁	0.2- 0.7	2-12	0.3-0.4	2-3
A ₂	0.3- 1.5	3-16	0.3-0.3	2-2
B ₁	0.4- 4.0(8.7)#	1-17(35)#	0.3-0.4	1-2
B ₂	0.4- 3.8	1-21	0.3-0.5	1-2
C	0.7- 5.3	1- 6	---	---
Total Extracted				
A ₁	0.6- 1.4	4-16	0.5-0.6	3-3
A ₂	0.6- 2.2	4-22	0.5-0.6	4-4
B ₁	0.7- 6.4	3-35	0.5-0.6	2-5
B ₂	0.7-12.4	1-27	0.6-0.8	1-4
C	3.3-17.6	5-19	---	---

#Excessive amounts found only in one profile in each case.

Data obtained from twenty solonized area profiles and four normal area profiles.

TABLE VI. Values of α and β for the different cases of the model. The values of α and β are given in the first and second columns respectively. The values of α and β are given in the first and second columns respectively.

Case		Values of α and β		Position
Case	Values of α and β	Case	Values of α and β	
Case I				
1-1	0.0-0.0	1-1	0.0-0.0	1
1-2	0.0-0.0	1-2	0.0-0.0	2
1-3	0.0-0.0	1-3	0.0-0.0	3
1-4	0.0-0.0	1-4	0.0-0.0	4
1-5	0.0-0.0	1-5	0.0-0.0	5
1-6	0.0-0.0	1-6	0.0-0.0	6
1-7	0.0-0.0	1-7	0.0-0.0	7
1-8	0.0-0.0	1-8	0.0-0.0	8
1-9	0.0-0.0	1-9	0.0-0.0	9
1-10	0.0-0.0	1-10	0.0-0.0	10
1-11	0.0-0.0	1-11	0.0-0.0	11
1-12	0.0-0.0	1-12	0.0-0.0	12
1-13	0.0-0.0	1-13	0.0-0.0	13
1-14	0.0-0.0	1-14	0.0-0.0	14
1-15	0.0-0.0	1-15	0.0-0.0	15
1-16	0.0-0.0	1-16	0.0-0.0	16
1-17	0.0-0.0	1-17	0.0-0.0	17
1-18	0.0-0.0	1-18	0.0-0.0	18
1-19	0.0-0.0	1-19	0.0-0.0	19
1-20	0.0-0.0	1-20	0.0-0.0	20
1-21	0.0-0.0	1-21	0.0-0.0	21
1-22	0.0-0.0	1-22	0.0-0.0	22
1-23	0.0-0.0	1-23	0.0-0.0	23
1-24	0.0-0.0	1-24	0.0-0.0	24
1-25	0.0-0.0	1-25	0.0-0.0	25
1-26	0.0-0.0	1-26	0.0-0.0	26
1-27	0.0-0.0	1-27	0.0-0.0	27
1-28	0.0-0.0	1-28	0.0-0.0	28
1-29	0.0-0.0	1-29	0.0-0.0	29
1-30	0.0-0.0	1-30	0.0-0.0	30
1-31	0.0-0.0	1-31	0.0-0.0	31
1-32	0.0-0.0	1-32	0.0-0.0	32
1-33	0.0-0.0	1-33	0.0-0.0	33
1-34	0.0-0.0	1-34	0.0-0.0	34
1-35	0.0-0.0	1-35	0.0-0.0	35
1-36	0.0-0.0	1-36	0.0-0.0	36
1-37	0.0-0.0	1-37	0.0-0.0	37
1-38	0.0-0.0	1-38	0.0-0.0	38
1-39	0.0-0.0	1-39	0.0-0.0	39
1-40	0.0-0.0	1-40	0.0-0.0	40
1-41	0.0-0.0	1-41	0.0-0.0	41
1-42	0.0-0.0	1-42	0.0-0.0	42
1-43	0.0-0.0	1-43	0.0-0.0	43
1-44	0.0-0.0	1-44	0.0-0.0	44
1-45	0.0-0.0	1-45	0.0-0.0	45
1-46	0.0-0.0	1-46	0.0-0.0	46
1-47	0.0-0.0	1-47	0.0-0.0	47
1-48	0.0-0.0	1-48	0.0-0.0	48
1-49	0.0-0.0	1-49	0.0-0.0	49
1-50	0.0-0.0	1-50	0.0-0.0	50
1-51	0.0-0.0	1-51	0.0-0.0	51
1-52	0.0-0.0	1-52	0.0-0.0	52
1-53	0.0-0.0	1-53	0.0-0.0	53
1-54	0.0-0.0	1-54	0.0-0.0	54
1-55	0.0-0.0	1-55	0.0-0.0	55
1-56	0.0-0.0	1-56	0.0-0.0	56
1-57	0.0-0.0	1-57	0.0-0.0	57
1-58	0.0-0.0	1-58	0.0-0.0	58
1-59	0.0-0.0	1-59	0.0-0.0	59
1-60	0.0-0.0	1-60	0.0-0.0	60
1-61	0.0-0.0	1-61	0.0-0.0	61
1-62	0.0-0.0	1-62	0.0-0.0	62
1-63	0.0-0.0	1-63	0.0-0.0	63
1-64	0.0-0.0	1-64	0.0-0.0	64
1-65	0.0-0.0	1-65	0.0-0.0	65
1-66	0.0-0.0	1-66	0.0-0.0	66
1-67	0.0-0.0	1-67	0.0-0.0	67
1-68	0.0-0.0	1-68	0.0-0.0	68
1-69	0.0-0.0	1-69	0.0-0.0	69
1-70	0.0-0.0	1-70	0.0-0.0	70
1-71	0.0-0.0	1-71	0.0-0.0	71
1-72	0.0-0.0	1-72	0.0-0.0	72
1-73	0.0-0.0	1-73	0.0-0.0	73
1-74	0.0-0.0	1-74	0.0-0.0	74
1-75	0.0-0.0	1-75	0.0-0.0	75
1-76	0.0-0.0	1-76	0.0-0.0	76
1-77	0.0-0.0	1-77	0.0-0.0	77
1-78	0.0-0.0	1-78	0.0-0.0	78
1-79	0.0-0.0	1-79	0.0-0.0	79
1-80	0.0-0.0	1-80	0.0-0.0	80
1-81	0.0-0.0	1-81	0.0-0.0	81
1-82	0.0-0.0	1-82	0.0-0.0	82
1-83	0.0-0.0	1-83	0.0-0.0	83
1-84	0.0-0.0	1-84	0.0-0.0	84
1-85	0.0-0.0	1-85	0.0-0.0	85
1-86	0.0-0.0	1-86	0.0-0.0	86
1-87	0.0-0.0	1-87	0.0-0.0	87
1-88	0.0-0.0	1-88	0.0-0.0	88
1-89	0.0-0.0	1-89	0.0-0.0	89
1-90	0.0-0.0	1-90	0.0-0.0	90
1-91	0.0-0.0	1-91	0.0-0.0	91
1-92	0.0-0.0	1-92	0.0-0.0	92
1-93	0.0-0.0	1-93	0.0-0.0	93
1-94	0.0-0.0	1-94	0.0-0.0	94
1-95	0.0-0.0	1-95	0.0-0.0	95
1-96	0.0-0.0	1-96	0.0-0.0	96
1-97	0.0-0.0	1-97	0.0-0.0	97
1-98	0.0-0.0	1-98	0.0-0.0	98
1-99	0.0-0.0	1-99	0.0-0.0	99
1-100	0.0-0.0	1-100	0.0-0.0	100

The values of α and β are given in the first and second columns respectively. The values of α and β are given in the first and second columns respectively.

8 to 38 per cent. The m.e. of exchange sodium in the solonized area profiles range from 0.2 to 4.0 m.e., being higher than the normal soil area amounts of 0.3 to 0.5 m.e. Percentages show 1 to 21 per cent range for exchange sodium for the solonized area profiles compared with 1 to 3 per cent of exchange sodium in the normal soil areas. Total extracted bases (water soluble plus the exchange bases), also point to the same conclusion. The range of the total extracted sodium from the solonized area profiles is from 0.6 m.e. to 12.4 m.e., as compared to the normal soil profile sodium limits of 0.5 m.e. to 0.8 m.e. Percentages of total extracted sodium vary from 1 to 35 per cent in the solonized area profiles, and from 1 to only 5 per cent in the profiles of the normal area.

It would seem that such differences in sodium content and proportion, as are shown here to exist between the soils of normal areas and those of solonized areas, indicate that the occurrence of solonized soils could be correlated with the presence of greater quantities or proportions of sodium in the soil.

The so-called "solonetz" soils of Alberta appear to contain much the same amount and proportions of both water soluble and exchangeable bases as do other soils with this structure in various parts of America. Kelley (17) has published analyses on similar soils occurring in California. He found in the seven profiles studied that amounts of water soluble salts increased with increasing depth, and that Na salts predominated. Also, the sum of the exchange bases found varied from 6.5 m.e.

in the A_1 horizons to 33.8 m.e. in the B_2 . The percentage of Na in the four exchangeable bases determined varied from 2 per cent in the A_1 to 29 per cent in the B_2 horizons of these California profiles.

In the Alberta solonized soils studied, replaceable K was not determined, but it usually occurs in very low amounts and it will not be considered in this discussion. The sum of exchangeable bases found in these Alberta soils varied from 5.7 m.e. in A horizons to 77 m.e. in the B_2 horizons (the latter amount is taken from total exchange capacity analyses). The amount of water soluble salts also increase with depth, and Na salts are often predominant.

Kelley (17) and Mitchell and Riecken (19) found definite increases of replaceable Mg with the depth of horizon, where it becomes the dominant replaceable base, but did not associate its occurrence with the development of the solonized profile. They concluded that the greater amounts of Mg present in the B horizons was associated with the greater degree of downward movement of materials in these profiles. Kelley points out however the important point that Mg clays are much more colloidal than Ca clays. Sushko (33) concludes that the amount of exchange Mg present is correlated to the degree of solodization in the profile, but does not associate the presence of this base with the evolution of the profile.

No such concentrations or dominance of replaceable Mg in the lower profiles of the Alberta solonetzic soils was observed in this study, Ca being the dominant base in practically all cases. This dominance of exchange Ca however may

be due to some extent to errors in the amounts of exchange Ca determined, due to the presence of carbonates in most of the B horizons studied.

Murphy and Daniel (20) have reported on the exchangeable Na content of the exposed B₁ horizons in the solonetzic soils of Oklahoma, where it varies in amount from 1.6 m.e. to 11.9 m.e. This is considerably higher than the amounts of exchangeable Na found in the B₁ horizons of Alberta solonetzic soils, where it ranged in amounts from 0.4 m.e. in the more normal B₁ horizons, to 8.7 m.e. in profiles which were heavily solonized.

Mitchell and Riecken (19) state that slight unsaturation of the A horizon is a common occurrence in the solonetzic soils of Saskatchewan. In the present study with Alberta soils, unsaturation of the A horizon appeared to be present in only two of the profiles studied. According to the Gedroiz theory, the H ions of the water percolating through the solonetz for a long time would gradually replace Na, thus forming hydrogen complexes or base unsaturated soils. However, if the soil contains CaCO₃, the Ca ions will gradually displace the Na and convert the solonetz into a normal soil. In the profile (Table III) where unsaturation was most evident, the amount of CaCO₃ present was extremely small. It would seem that in most cases in these Alberta soils that the relative abundance of CaCO₃ present, and the low precipitation occurring in these areas would tend to prevent unsaturation as a normal feature of these soils.

Total exchange bases determined in the A horizons of the solonized area varied from 5.7 to 18.1 m.e. per 100 grams of

soil, whereas the normal soil area to the north varied from 16.0 to 21.2 m.e. This is lower than amounts found by Holowaychuk (11) in the black and in the grey wooded Alberta soil zones. However, it does agree with those reported by Page and Williams (26) found in Rothamsted soils, where soils contained 12-16 m.e. and in general, are slightly lower than those of Illinois soils reported by Bray (3) where total exchange bases as high as 33 m.e. occurred.

Solonized soils in Alberta appear to be the result of limited precipitation and a topography which tends to give incomplete drainage of relatively large areas. Soil type may be considered as a secondary and more localized factor. The mean annual precipitation in the more solonized area is approximately 12 inches, with the high evaporation rate which is typical of such semi-arid regions. Solonization, however, does occur to a limited extent in the Edmonton region where the annual precipitation is approximately 18 inches, with a much lower evaporation rate.

The relative absence of solonization on slopes and rolling topography in the solonized area has consistently been observed. The results presented here indicate that the presence of strongly solonized areas can be correlated with the presence of slightly larger amounts of sodium, in either the water soluble or exchange form. It appears that considerable movement of sodium has occurred from the surrounding soils, which now appear more normal in structure, into the present strongly solonized more level land where it has accumulated, probably due to a more impervious subsoil. These conclusions agree with those of de'Sigmond (5).

Surface erosion appears to be related to the degree of solonization and the soil type. The results presented indicate that solonization of the profile may be to some degree correlated with sodium content, which is one cause of deflocculation and impermeability. It seems possible that erosion may be directly related to the sodium content of such soils. Joel (12) has suggested that erosion may be correlated with the comparative closeness of the underlying non-calcareous parent shales, since the glacial till appears to be relatively shallow or absent in these areas.

Soil profiles which exhibit extremely weak solonetz morphology, even though occurring in heavily solonized areas, do not differ materially in base content or proportion from soil profiles of normal areas with the exception of the greater increase of sodium with depth. This greater concentration of sodium in the lower horizons in the solonized areas appears to be a direct result of incomplete drainage combined with the lower precipitation of the solonized area in general.

The analysis of the one cultivated eroded profile which was heavily solonized, indicates that cultivation is of little value in reclaiming such lands unless the impervious B horizon is disturbed. The relative proportion of bases present after surface cultivation, have not altered significantly, indicating probable small physical change in the condition of the subsoil.

Summary

The so-called morphological solonetz soils of Alberta do not belong to the true alkali soils, but are alkalized to a lesser degree. The profile morphology is typically solonetzic, but lacks the solonetz chemistry. This is in agreement with other investigations carried out in several parts of America.

No significant differences exist in base content or proportion of bases, between eroded and non-eroded solonetz profiles which are immediately adjacent to each other. Slight increases in water soluble sodium occur in the B_2 horizons of the eroded profile, apparently being in the sulphate form. This increase may be explained by the relatively impervious B_1 horizon preventing the percolation of water through the profile. Any precipitation evaporates rapidly from the exposed B_1 surface.

Significant differences in base content and proportions were observed between very weakly solonized profiles and those which showed a decided solonetz morphology. In several cases, these profiles were located only a few yards apart. This feature was especially marked in two sandy loam profiles which were compared (Table II Group IX), where the differences in base proportion and amount were attributed to differences in depth at which the impervious subsoil occurred.

In all solonized profiles analyzed, exchangeable sodium constituted a greater percentage of the exchangeable bases in the strongly solonized B_1 horizons, than occurred in the more weakly solonized adjacent horizons.

The amount and proportion of sodium (to the divalent bases), appears to be related to the degree of solonization. Strongly solonized profiles contained relatively greater amounts of extracted sodium than the more weakly solonized profiles.

Magnesium, either in exchangeable or totally extracted quantities, did not increase consistently with the depth of profile or with the degree of solonization. The inconsistency in the amounts of this base present, indicates that it probably has not been as important as sodium in the genesis of the solonized profile. Calcium was present in relatively much greater quantities than magnesium, in practically all horizons, even when a correction is allowed for soluble calcium that was often present in the lower B horizons.

Profiles from normal areas, and apparently normal profiles from solonized areas were compared. The only significant difference was the higher concentration of water soluble sodium in the lower horizons of the solonized area profiles. Exchange sodium was not significantly greater.

The relative ratio of exchange sodium to the divalent bases found in Alberta solonetz soils, is low in relation to some soil areas reported in California and in Russia.

Total exchangeable bases in these soils are appreciably lower than those reported in the soils of the black soil zone in Alberta by Holowaychuk. This is probably due to the lower content of organic matter in these soils. The amounts of exchangeable bases found agree well with those obtained in similar soils occurring in Saskatchewan. Rothamsted and Illinois soils

appear to be much the same in this respect.

Base unsaturation of the A horizons does not appear to be a characteristic feature of these solonetz soils. Definite unsaturation was found in only two of the profiles studied. Unsaturation apparently does not occur in the normal soils of the area.

The relative solubility effects of water and normal ammonium acetate upon lime plaster, calcium carbonate and hydrated calcium sulphate are reported. Differences in solubility effect tend to introduce severe error in the determination of exchange bases.

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